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## The Annular Eclipse of the Sun on April 7, 1940

By C. T. ELVEY

The eclipse of the sun on April 7, 1940, which entered the United States in the Big Bend Region of Western Texas and crossed the Southern States to northern Florida, was observed under excellent atmospheric conditions in Texas. There were comparatively few scientific expeditions, however, since the eclipse was only an annular one. An annular eclipse does not give an opportunity of observing the atmosphere of the sun—the corona and the chromosphere—as does a total eclipse, and, consequently, the number of problems is quite limited.

Before discussing the Yerkes and McDonald Observatories' expedition to observe the eclipse, perhaps we should describe briefly the circumstances which produce an annular eclipse. The plane of the moon's orbit makes an angle with the plane of the ecliptic with the result that an eclipse of the sun can occur only when the moon is crossing through or near the plane of the ecliptic at the time it is in conjunction with the sun. If the moon in its orbit is within 18° of its node when it is at conjunction then it is possible to have an eclipse. This limiting case, however, produces only partial eclipses, and the moon must be within 11° of the node if a central eclipse is to be produced. In a central eclipse the line joining the centers of the sun and moon strikes the earth, or in other words, the observer on this line will see the moon transit directly across the center of the disk of the sun.

The shadow cast by the moon is, of course, cone-shaped and the distance of the apex of the cone from the moon depends upon the sizes of the sun and the moon and the distance between the two objects. Owing to the variation in the distance of the moon from the sun, the length of the shadow at the time of conjunction varies from 228,120 to 235,700 miles. The mean distance of the moon from the earth's surface, 234,900 miles, is greater than the mean length of the shadow of the moon, and, consequently, under average conditions the shadow will not reach the earth. The moon, however, varies considerably in its distance from the earth, the limiting distances from the surface being 217,600 and 249,000 miles, thus when the moon is close to the earth we have the situation represented in Figure 1 (upper diagram), that is, a total eclipse of the sun for all places on the earth's surface between the points "x" and "y" of the diagram. As the moon moves in its orbit and the earth rotates on

its axis, the shadow is caused to sweep across the earth's surface in an easterly direction.

The average distance of the moon from the earth's surface is greater than the average length of the moon's shadow and, consequently, there will be a greater number of eclipses represented by the lower diagram of Figure 1. Since the tip of the shadow does not reach the surface of the earth, all those observing between the positions "x" and "y" will see the moon projected against the sun's disk, those at point "x" will see the

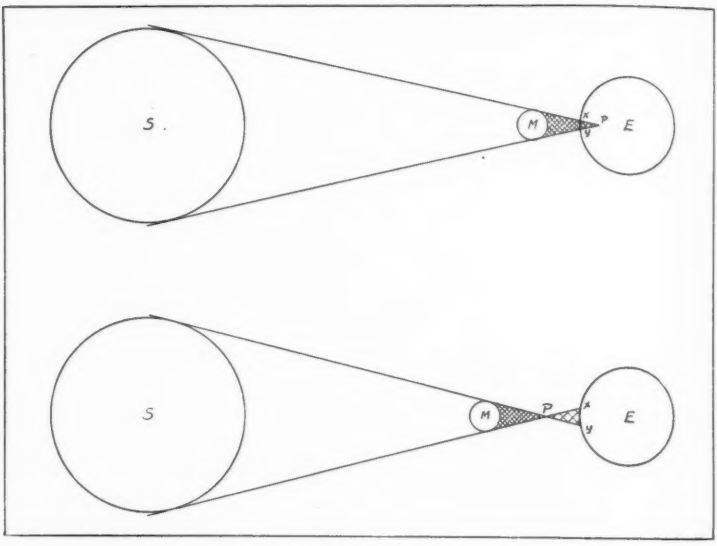


FIGURE 1
THE RELATIVE POSITIONS OF THE EARTH'S SURFACE AND THE SHADOW OF THE MOON AT TOTAL AND ANNULAR ECLIPSES OF THE SUN

lower limbs in coincidence while those at "y" will see the upper limbs in coincidence. The observers at the midpoint between "x" and "y" will see the moon centered on the sun's disk and the eclipse will appear as a uniform ring, thus accounting for the name of "ring" or annular eclipse.

The magnitude of an eclipse is the ratio of the angular diameter of the moon to that of the sun. In annular or partial eclipses this ratio is less than unity. The magnitude of the April 7, 1940, eclipse was 0.93, thus showing that the moon covered 93 per cent of the diameter of the sun. A very simple computation will give the amount of the sun's disk left uneclipsed and, if the sun had no darkening at the limb, it would give us the percentage of the sunlight remaining. By making reasonable assumptions for the darkening at the limb we estimate that the decrease in the light from the sun at the middle of the eclipse would be 3 or 4 magnitudes. In spite of the articles appearing in the newspapers mentioning

that the decrease in brightness of the sun would not be so very great at this eclipse, most of the persons observing it in Western Texas were disappointed because it did not get darker. In reality the illumination at the middle of the eclipse was about the same as that on a day when the sun is covered by a thin cloud. Let us consider the apparent brightness of the sun, which is of magnitude —27. With a decrease of 3 or 4 magnitudes at the middle of the eclipse the apparent brightness of the uneclipsed portion of the sun would be equal to magnitude —23 or —24. The apparent brightness of the full moon is of magnitude —13, hence the sun at the time of the annular eclipse of April 7 would be 10 magnitudes brighter than the full moon. The illumination was approximately 10,000 times that of the full moon.

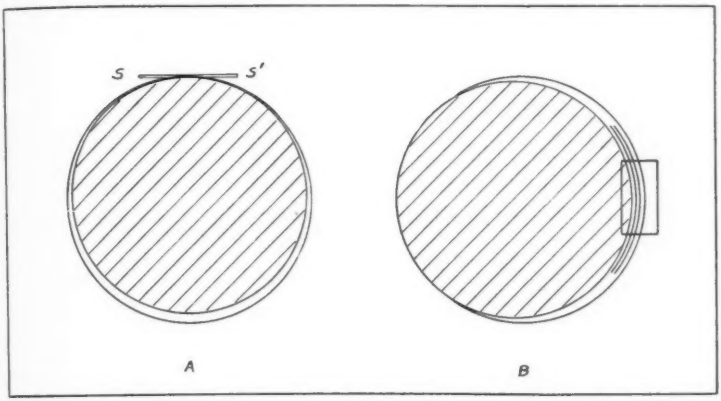


FIGURE 2
ANNULAR ECLIPSE OF THE SUN SHOWING POSITIONS FOR MAKING OBSERVATIONS AS DISCUSSED IN THE TEXT

The change in temperature during the eclipse was perhaps more noticeable to the public who came to see the eclipse in the vicinity of our camp. In a semi-arid country and at an altitude of 5000 feet above sea-level, a person depends a great deal upon the radiant heat from the sun and when 90 per cent of it is cut off by an eclipse it is very noticeable. The temperature of the air dropped approximately seven degrees during the eclipse.

As mentioned above, the problems which can be solved from observations of an annular eclipse are few in comparison with those at a total eclipse. Of interest to the physicists are observations of the ionosphere, or ionized layers of the upper atmosphere which affect the long-distance transmission of radio waves. The sun's ultraviolet light causes the upper atmosphere to be ionized and at the time of an eclipse the sunlight is being cut off at an accurately known rate up to mid-eclipse, and then increases again. The observations of the changes in the ionization during

the eclipse give important information concerning the physical state of the upper atmosphere. This problem was attacked by physicists from the Carnegie Institution of Washington.

Another problem which is of interest to the astrophysicist is the lower atmosphere of the sun, or the chromosphere. This can be observed to some extent even without an eclipse but the scattered light in the earth's atmosphere interferes greatly. Although a total eclipse is better for chromospheric studies, yet an annular eclipse, such as of April 7, can give valuable information. Figure 2-A shows the conditions of the annular eclipse as it would be observed from a point near the limit of the central belt of the eclipse, say at point "x" or "y" in Figure 1. The moon is moving horizontally across the diagram of Figure 2 and in the position shown by SS′ the moon will cut off the photosphere of the sun for a fairly long interval of time, but leave the chromosphere visible. By projecting the image of the sun so that this region falls on the slit of a spectrograph, SS′, a long exposure can be given without much trouble from scattered light of the bright portion of the sun. This problem was planned by one observing party for this eclipse but unfortunately it could not be carried out.

The Yerkes and McDonald Observatories at the suggestion of Dr. P. Swings made a study of the problem of darkening at the limb of the sun. Those who have tried to photograph the sun have found that the edges would be underexposed while the center was correctly exposed. This is due to the light from the photospheric levels having to come through a much greater thickness of the sun's atmosphere at the edge of the sun's disk than at the center. The decrease in light is most rapid near the edge of the sun and observations are very difficult to make on the uneclipsed sun on account of the unsteadiness of the terrestrial atmosphere,—twinkling,—hence causing the observer to measure light from several adjoining areas of the sun's disk as well as the one in which he is interested. At an eclipse of the sun, the moon does the selecting of the areas of the sun for the observer without any interference from twinkling and thus he has an excellent opportunity to study the darkening at the limb. The observer can project the image of the sun on a small rectangular aperture such as is shown in Figure 2-B. By placing his measuring equipment directly behind it, he will measure the total amount of light reaching his receiver, and as the moon progresses across the disk of the sun it successively cuts off various areas, and from the accurately known motions of the moon and the times noted on his records the astronomer can evaluate the amount of light coming from each area, and hence obtain a measure of the darkening at the limb of the sun.

This type of investigation has been done for the visual and photographic regions of the spectrum, but comparatively little is known concerning the darkening at the limb for the infra-red region. We decided to work in the region of about $3\mu$, using a thermocouple for a receiving element and suitable filters so as to limit the region of the spectrum.

The design and construction of the thermocouple and the recording equipment was carried out by Drs. Fred T. Rogers, Jr., and Philip C. Keenan of Yerkes Observatory and it will be described in detail along with the discussion of the results obtained at the eclipse. Briefly, the thermocouple had a receiving surface 1x2 mm which was placed at the position represented by the rectangle in Figure 2-B, the image being formed with a 6-inch reflecting telescope at the Newtonian focus. A diagonal piece of glass, or filter, reflected a portion of the sunlight which was viewed with an eyepiece, thus making it possible to guide the telescope throughout the recording. The telescope was driven by a synchronous motor, the alternating current being furnished by a motor-generator set. The frequency of the alternating current could be controlled by observing a calibrated frequency meter and regulating a rheostat in the shunt field of the direct current motor. Records of the frequency were made during the eclipse.

The device to record the thermoelectric current was placed on a separate pier with a pair of wires connecting the thermocouple and the sensitive recording galvanometer. The deflections of the galvanometer were recorded on film behind a narrow slit. The positions of the recording spot of light on the slit could be watched by an observer who would change the sensitivity of the galvanometer at intervals as needed through the eclipse.

Time was marked on the record by interruptions in the recording light through contacts mounted on a shaft of the driving clock which rotated once per second. A stop-watch was used to note the interval of time between the contact of the limbs of the sun and moon and a given point on the record, thus giving a check on the interval of time shown by the recording.

The eclipse camp was located at the headquarters of the Proposed Big Bend National Park in the Chisos Mountains, about 80 miles by road south of Marathon, Texas, and about 100 miles, airline, south-southeast of the McDonald Observatory. The site was about 8 miles north of the central line of the eclipse and at an elevation of 5200 feet, thus offering excellent conditions for observing the eclipse. This area is semi-arid and during the springtime a certain amount of dust may be present in the air, however, two days prior to the eclipse there were clouds and light showers which cleared the atmosphere of dust and on eclipse day we had an excellent photometric sky.

The members of our eclipse party, Dr. Fred T. Rogers, Jr., Mr. Walter Linke, Mr. Arch T. Garner and myself wish to express our appreciation to Mr. Kirk H. Scott, Superintendent of the Proposed Big Bend National Park, and to his staff, and also, to the officers of CCC Company No. 1856 for the assistance they furnished in making our expedition a very pleasant and successful one.

McDonald Observatory, April 22, 1940.

# Planetary Groupings Recorded in China

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On February 28, 1940, Mercury, Venus, Mars, Jupiter, and Saturn were visible as evening stars, the total spread in right ascension being only 2 hours and 35 minutes. This was reported in the press as a most unusual occurrence, but no reference was made to similar groupings recorded in the past. Several general astronomies consulted also make no mention of such events.

Chambers,[1] however, lists a number of proximities of three or more planets, as well as certain conjunctions of two planets which were remarkable because they happened to be so close in declination as to be visible together in the field of a telescope. Of these groupings, only two, one on September 15, 1186 A.D. and one on November 11, 1524 A.D., involved all five naked-eye planets.

The 1186 grouping first came to the attention of the present writers twenty-five years ago, when they were members of the faculty of Yale in China at Changsha, through a reference in the *Changsha Hsien Chi* or "Gazeteer of Changsha County." This is one of hundreds of county records containing a vast fund of historical, geographical, and sociological data. Volume 18, Section 33, pages 1-14 recorded special events portending good or bad luck, and contained entries regularly from 144 B.C. Astronomical notes were mostly credited to the *Tien Wen Chi* or "Astronomical Record" and to the *Wu Sing Chi* or "Records of the Five Planets in the Dynastic Histories." In the accounts of marvels and lucky and unlucky events the astronomical items were fairly numerous in the earlier centuries and up to 1223 A.D. Thereafter very few astronomical items were found and they were not so precise.

In reading these records it soon became noticeable that most of the eclipses and other celestial events mentioned took place in the constellation of *Chen,* which is the last of the 28 *fu* into which the Chinese divided the ecliptic to give the moon a daily position among the stars; *fu* often is translated "mansion," but that is perhaps too elaborate a word for what is more in the nature of the hotel room of a travelling salesman who makes a regular monthly round of one-night stands. This constellation corresponded to $\gamma$ and $\epsilon$ of Corvus.[2] There were also a few references to phenomena in the 27th *fu,* the constellation *Yi,* corresponding to $\alpha$ of Crater.[3]

[1] George F. Chambers, "A Handbook of Descriptive and Practical Astronomy," Vol. I, fourth edition, Oxford, 1889, pp. 68-71.
[2] S. Wells Williams, "A syllabic Dictionary of the Chinese Language," p. 824.
[3] *Ibid.*

According to ancient records assembled in Volume 1, pp. 1-9, of the *Changsha Hsien Chi*, it appears that these two constellations, *Yi* and *Chen*, were the celestial counterpart of the ancient Kingdom of *Ts'u*, which comprised the greater part of the present provinces of Hunan and Hupeh, while they were still undivided and southern Hunan was still largely unsettled. In the midst of *Chen* was a small star known as the Changsha star. To modify Kipling:

*Pat as a sum in division it goes—*
*(Every state had a star bespoke)*[4]

Thus it was natural that the annals of a Hunan county should record occurrences in *Chen*.

Under the date of the thirteenth year (1186 A.D.) of the *Shun Hsi* period of the Emperor *Hsiao Tsung* of the *Sung* Dynasty, was the following entry:

> [In the] intercalary Seventh Month the five planets were gathered together in *Chen*; [in the] Eighth Month, the sun, moon, and the five planets were all together in *Chen*.

The record of such an occurrence was a challenge to verify it. Although library facilities in Changsha at the time were very limited, there were fortunately at hand a few current years of the "American Ephemeris and Nautical Almanac," which gave the heliocentric coördinates of the planets. By counting back periods, with interpolation in the case of the outer planets for which the data were not available for dates an exact number of periods after 1186, it was possible to determine the heliocentric positions of the sun, moon, and the five planets at the given epoch, and from these the configuration as seen from the earth. It was something of a thrill to have five planets swim into our ken all together to confirm the record of the ancient chronicler.

The computations made in 1916 have long since been lost, but the phenomenon has again been verified by the easier method of using the convenient charts and tables given by Bartky.[5]

It was first determined, by counting back synodic months, that in 1186 A.D. the Chinese New Year, or new moon occurring when the sun is in the *sign* (not the constellation) of Aquarius, occurred on January 25 (Julian calendar), which hence was the first day of the First Month. The Seventh Month began on July 21 and the following month on August 20; since the sun was in the sign of Leo on both these dates, the latter month was an intercalary one, of which seven had to be inserted in the Chinese lunar calendar every nineteen years, in accordance with the

[4] "Rudyard Kipling's Verse, Inclusive Edition, 1885-1918," New York, 1919, p. 631, "Our Fathers of Old."

[5] Walter Bartky, "Highlights of Astronomy," University of Chicago Press, 1935, pp. 168-172 (for heliocentric positions), 180-181 (for right ascensions and declinations). Bartky's table of decimals for centuries runs only from the 15th to the 24th centuries A.D., inclusive, but is easily extended backward by subtracting for each century 100 times the reciprocal of the planet's period in years.

Metonic cycle. The next new moon, on September 18, 1186, was the first of the Eighth Month. Using Bartky's charts, the right ascensions of the bodies of the solar system were found to be as follows on that date:[6] Sun and moon, $12^h$; Mercury, $12^h\ 20^m$; Jupiter, $12^h\ 20^m$; Venus, $12^h\ 40^m$; Saturn, $12^h\ 50^m$; Mars, $13^h\ 10^m$. Thus the planets were all evening stars, extended within a range of about 13°, all setting within little more than an hour after sunset, and all close to *Chen,* whose right ascension is about $12^h\ 10^m$. The moon, of course, unlike the little man on the stair, was there but not visible, and Mercury and Jupiter were visible, if at all, only very close to the horizon and only under most favorable conditions.

The 1524 A.D. grouping mentioned by Chambers does not seem to be verified by the Bartky charts; in view of errors by Chambers mentioned below this perhaps is not surprising.

A similar occurrence in more modern times is mentioned in a letter of *Tseng Kuo-fan,* the great Chinese statesman and military leader. Writing to his home on September 5, 1861, in the midst of his campaign against the Taiping rebels, he said:

> *Koh Hsing* has arrived and I have received the joyous message that today at the *Mao* hour [5-7 A.M.] Anking was retaken. Opportunely it happens that the sun and moon rise together and the five planets are strung together. The Board of Astronomy memorialized the Throne in the Fifth Month that it portended unusual fortune. Anking's capture duly fulfills this.[7]

September 5, 1861, was a new moon, the first of the Eighth month. The Bartky charts give, within the limits of accuracy, the following right ascensions: Jupiter, $10^h\ 30^m$; sun, moon, Mercury, Mars, $11^h$; Saturn, $11^h\ 10^m$; Venus, $13^h$; all within a range of $1^h\ 30^m$ or 22° 30′. Thus, Jupiter was a morning star, Mercury and Mars very close to the sun, and Saturn and Venus evening stars. There was, therefore, no visible grouping of the five planets; a few days earlier, however, all except Mercury could have been seen, under favorable conditions, strung out as evening stars.

A still earlier Chinese record is mentioned by Chambers as follows:

> The earliest record we possess of an occurrence of this kind is of Chinese origin. It is stated that a conjunction of Mars, Jupiter, Saturn, and Mercury, in the constellation *Shi,* was assumed as an epoch by the Emperor *Chuen-ho,* and it has been found by MM. Desvignoles and Kirch that such a conjunction actually did take place on February 18, 2446 B.C., between 10° and 18° of Pisces. Another calculator, de Mailla, fixes upon

[6] Because of the small scale of the charts it is not practicable to read positions closer than 10 minutes of time. These right ascensions are based on an equinox of the present time; no correction has been made for precession, which would affect all equally, and not change the relative positions. Nor has any correction been made for changes in the positions of perihelia or other elements of the planetary orbits, which may be assumed to be of negligible effect, at least within the limits of accuracy of the charts.

[7] W. J. Hail, "Tseng Kuo-fan and the Taiping Rebellion," New Haven, 1927, p. 235.

February 9, 2441 B.C. as the date of the conjunction in question, and he states that the four planets named above were comprised within an arc of 12° extending from 15° to 27° of Pisces.[8]

Chambers adds the following remark, typical of an earlier generation:

It deserves mention that both the foregoing dates precede the usually received date of the Noachian deluge. It may therefore be that the planetary conjunction in question was ascertained at some subsequent time.[9]

The planetary positions on the above two dates, as determined by Bartky's charts, showed no close grouping. Reference to Bailly's and de Mailla's original works then revealed that Chambers had quoted both dates wrongly, and that they should be February 28, 2449 B.C. and February 9, 2461 B.C., respectively. But again the positions, as determined by Bartky's charts, showed no close grouping of the four planets named.

De Mailla, a Jesuit missionary at the court of the Emperor *Kang Hsi*, gives his computations in some detail in letters to a M. Freret, who disagreed with him in regard to matters of Chinese chronology.[10] These letters were written in 1737 and 1738, and were included in de Mailla's "Histoire," published in 1777, about thirty years after his death. Bailly in his book, published in 1775, apparently did not know of the unpublished work of de Mailla, and accepts the agreeing computations of Desvignoles and Kirch, whose original papers are not available to the present writers. It must be left for some one more skilled than an amateur astronomer to determine why two different dates were arrived at by the three computers, and why neither of these dates is confirmed by the use of Bartky's charts.

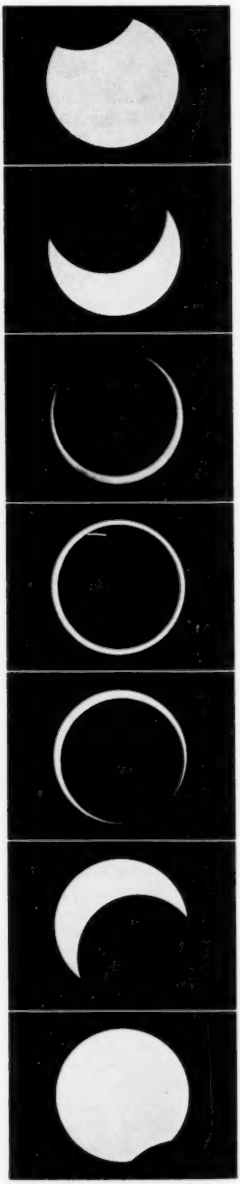
When we consider that these very remote dates concern a period of legendary, if not of mythological, history, we are not at all surprised that astronomy does not necessarily confirm them. It is, on the contrary, one of the delights of the historian to find that astronomy (even if chiefly for astrological purposes) was far enough advanced to make the records of such an occurrence as long ago as 1186 A.D. substantially accurate.

April 15, 1940.

[8] *Op. cit.*, pp. 70-71. Chambers gives references to his sources as [full titles supplied here from the originals]: Bailly, "Histoire de l'Astronomie Ancienne, depuis son Origine jusqu'a l'Etablissement de l'Ecole d'Alexandrie," Paris, 1775, p. 345; and Joseph-Anne-Marie de Moyriac de Mailla, "Histoire Générale de la Chine ou Annales de cet Empire," Traduites du Tong-Kien-Kang-Mou, Paris, 1777, Vol. I, p. clv. He states, evidently quoting from Bailly, that the original memoirs by Desvignoles and by Kirch appeared in *Memoires de l'Academie de Berlin*, Vol. III, p. 166, and Vol. V, p. 193, respectively.

[9] *Ibid.*

[10] *Op. Cit.*, pp. lxxv-clxxxiv, especially cliii-clxi.



PHOTOGRAPHS OF THE ANNULAR ECLIPSE OF APRIL 7, 1940.

# Observations of the Annular Eclipse of April 7, 1940

By D. V. GUTHRIE and W. A. RENSE

The recent annular eclipse of the sun was visible along a path about 156 miles in width passing through the Gulf states. Realizing that the observatory of the Louisiana State University was probably more favorably located for observation of the eclipse than any other, being situated only about 14 miles south of the central line, we made plans for observing several features of the eclipse and for photographing it.

The telescope, a Clark refractor of 11½ inches aperture, was installed a year ago. A camera designed for general astronomical photographic work with the telescope was completed quite recently. This camera was constructed to our specifications in the department instrument shop.

The accompanying pictures, somewhat reduced in size from the original negatives, illustrate different phases of the eclipse. Beginning at the right, they were taken at the following times:

No. 1, $2^h\ 46^m\ 17^s$ C.S.T.; No. 2, $3^h\ 30^m\ 48^s$; No. 3, $3^h\ 55^m\ 47^s$; No. 4, $3^h\ 58^m\ 46^s$; No. 5, $4^h\ 01^m\ 45^s$; No. 6, $4^h\ 22^m\ 50^s$; No. 7, $5^h\ 15^m\ 05^s$.

The photographs were taken on high-contrast lantern slide plates, using a Wratten No. 12 filter. The objective was stopped down to 2 inches, and the exposure was 1/20 second. The 172-inch focal length of the telescope enabled us to obtain an image of the sun a little more than 1½ inches in diameter.

Picture No. 4 was taken at the exact middle of the eclipse. The slight dissymmetry of the ring due to the observatory's being 14 miles south of the central line is clearly evident. Bailey's "beads" were seen during the eclipse and, although they do not show clearly on the prints, are present on the original negative for picture No. 3. The "beads" were not very conspicuous and lasted about three seconds at the beginning and again at the end of the annular phase. The conditions for observing were ideal—a warm, cloudless afternoon. A careful watch was kept for the flash spectrum, but without success. Venus was quite conspicuous, remaining easily visible for perhaps an hour after the annular phase was passed, but no other planets were noted. No shadow bands were seen.

The observed times of the important phases of the eclipse checked with the predicted times within experimental error. Short-wave radio communication between Louisiana State University station (W5YW) and other stations in the path was not appreciably affected. There was no evidence of fading, and no change in the average intensity of the signals. However, a slight increase in static was noticed during the annular phase.

The public was invited to the observatory during the eclipse. Many took advantage of the invitation and were on hand to watch the proceedings. They were not permitted to interfere in any way with the scheduled program. A large image of the sun formed by the three-inch telescope finder was thrown on a screen so that every one could conveniently observe the progress of the eclipse. Many spectators were struck by the unusual appearance of the shadows of the trees, pinhole images in the form of small rings being formed by the interstices between the leaves during the annular phase. And thus Baton Rouge's only annular eclipse for many centuries passed into history.

LOUISIANA STATE UNIVERSITY,
UNIVERSITY, LOUISIANA, MAY 3, 1940.

# List of Stars Nearer than Five Parsecs

*By* PETER VAN DE KAMP

The present list is a revision of the list published in this journal ten years ago.* Only modern photographic parallax determinations with long-focus instruments have been included; the values have been reduced to absolute by adding a statistical correction for the parallax of the reference stars. Stars with an absolute parallax value below 0″.200 have been excluded. For each parallax value a weight has been adopted based on the number of independent determinations; assuming a probable error of 0″.010 for a "normal" parallax determination, the final probable errors have been derived. The relative probable error $r_d/d$ of the dis-

*POPULAR ASTRONOMY, **38**, 17 (1930).

TABLE I—List of Stars nearer than Five Parsecs

| No. | Name | 1900 R.A. | 1900 Decl. | Visual Magnitude | Spectrum |
|---|---|---|---|---|---|
| 1. | Sun | | | | G0 |
| 2. | α Centauri *A* | $14^h32^m8$ | −60°25′ | $0^m3$ | G4 |
| 3. | " *B* | " | " | 1.7 | K1 |
| 4. | " *C* | 14 22.9 | −62 15 | 11 | M |
| 5. | Barnard's Star | 17 52.9 | + 4 25 | 9.7 | M6 |
| 6. | Wolf 359 | 10 51.6 | + 7 37 | 13.5 | M8 |
| 7. | Lalande 21185 | 10 57.9 | +36 38 | 7.6 | M2 |
| 8. | Sirius *A* | 6 40.7 | −16 35 | − 1.6 | A0 |
| 9. | " *B* | " | " | 7.1 | A5 |
| 10. | Ross 154 | 18 43.6 | −23 57 | 11 | M6 |
| 11. | Ross 248 | 23 37.0 | +43 40 | 12 | M6 |
| 12. | ε Eridani | 3 28.2 | − 9 48 | 3.8 | K0 |
| 13. | τ Ceti | 1 39.4 | −16 27 | 3.6 | K0 |
| 14. | Procyon *A* | 7 34.1 | + 5 29 | 0.5 | F3 |
| 15. | " *B* | " | " | 10.8 | ... |
| 16. | 61 Cygni *A* | 21 2.4 | +38 15 | 5.6 | K5 |
| 17. | " *B* | " | " | 6.3 | K6 |
| 18. | ε Indi | 21 55.7 | −57 12 | 4.7 | K5 |
| 19. | Σ 2398 *A* | 18 41.8 | +59 29 | 8.9 | M4 |
| 20. | " *B* | " | " | 9.7 | M5 |
| 21. | Groomb. 34 *A* | 0 12.7 | +43 27 | 8.1 | M1 |
| 22. | " *B* | " | " | 10.9 | M6 |
| 23. | BD −12°4523 | 16 24.7 | −12 25 | 9.7 | M4 |
| 24. | Lacaille 9352 | 22 59.4 | −36 26 | 7.4 | M2 |
| 25. | Ross 614 *A* | 6 24.3 | − 2 44 | 11 | ... |
| 26. | " *B* | " | " | 13? | ... |
| 27. | Luyten's Star | 7 22.4 | + 5 32 | 10.1 | M4 |
| 28. | Lacaille 8760 | 21 11.4 | −39 15 | 6.6 | M1 |
| 29. | Krüger 60 *A* | 22 24.5 | +57 12 | 9.8 | M4 |
| 30. | " *B* | " | " | 11.3 | M6 |
| 31. | Kapteyn's Star | 5 7.7 | −44 59 | 8.8 | M0 |
| 32. | Groomb. 1618 | 10 5.3 | +49 58 | 6.8 | K6 |
| 33. | van Maanen's Star | 0 43.9 | + 4 55 | 12.3 | F0 |
| 34. | Ross 780 | 22 47.9 | −14 47 | 9.5 | ... |
| 35. | CD −46°11540 | 17 21.1 | −46 47 | 9.4 | ... |
| 36. | AOe 17415-6 | 17 37.0 | +68 26 | 9.1 | M4 |
| 37. | Wolf 424 *A* | 12 28.4 | + 9 34 | 12.6 | M8 |
| 38. | " *B* | " | " | 12.6 | |
| 39. | CD −44°11909 | 17 29.8 | −44 14 | 10.0 | ... |
| 40. | BD +43°4305 | 22 42.5 | +43 48 | 10.2 | M5e |
| 41. | CD −37°15492 | 23 59.5 | −37 51 | 8.3 | M3 |
| 42. | CD −49°13515 | 21 26.9 | −49 26 | 8.6 | Ma |
| 43. | Altair | 19 45.9 | + 8 36 | 0.9 | A5 |
| 44. | $o^2$ Eridani *A* | 4 10.7 | − 7 49 | 4.5 | G5 |
| 45. | " *B* | " | " | 9.2 | B9 |
| 46. | " *C* | " | " | 10.7 | M5e |
| 47. | A.C. +79°3888 | 11 41.3 | +79 14 | 11.0 | M4 |

TABLE I—CONTINUED

| Annual Proper Motion | Parallax | | Distance in light years | | Abs. vis. mag. | Visual luminosity | No. |
|---|---|---|---|---|---|---|---|
| | | | | | +5 | 1 | 1. |
| 3".68 | ".761 ± ".005 | | 4.28 | ± .03 | 4.7 | 1.3 | 2. |
| " | " | " | " | " | 6.1 | .36 | 3. |
| 3.85 | " | " | " | " | 15.4 | .000069 | 4. |
| 10.30 | .539 | 3 | 6.05 | .03 | 13.4 | .00044 | 5. |
| 4.84 | .408 | 14 | 8.0 | .3 | 16.6 | .000023 | 6. |
| 4.78 | .389 | 6 | 8.4 | .1 | 10.6 | .0058 | 7. |
| 1.32 | .381 | 4 | 8.6 | .1 | 1.3 | 30. | 8. |
| " | " | " | " | " | 10.0 | .010 | 9. |
| .74 | .359 | 10 | 9.1 | .3 | 13.8 | .00030 | 10. |
| 1.60 | .311 | 8 | 10.5 | .3 | 14.5 | .00016 | 11. |
| .97 | .302 | 6 | 10.8 | .2 | 6.2 | .33 | 12. |
| 1.92 | .299 | 6 | 10.9 | .2 | 6.0 | .40 | 13. |
| 1.25 | .295 | 4 | 11.1 | .1 | 2.9 | 6.9 | 14. |
| " | " | " | " | " | 13.2 | .00052 | 15. |
| 5.22 | .294 | 4 | 11.1 | .1 | 7.9 | .069 | 16. |
| " | " | " | " | " | 8.6 | .036 | 17. |
| 4.67 | .291 | 7 | 11.2 | .3 | 7.0 | .16 | 18. |
| 2.29 | .284 | 6 | 11.5 | .2 | 11.2 | .0033 | 19. |
| " | " | " | " | " | 12.0 | .0016 | 20. |
| 2.91 | .278 | 7 | 11.7 | .3 | 10.3 | .0076 | 21. |
| " | " | " | " | " | 13.1 | .00058 | 22. |
| 1.24 | .274 | 5 | 11.9 | .2 | 11.9 | .0017 | 23. |
| 6.87 | .271 | 7 | 12.0 | .3 | 9.6 | .014 | 24. |
| .97 | .262 | 5 | 12.4 | .2 | 13.1 | .00058 | 25. |
| " | " | " | " | " | 15? | .0001? | 26. |
| 3.73 | .261 | 7 | 12.5 | .3 | 12.2 | .0013 | 27. |
| 3.46 | .260 | 7 | 12.5 | .3 | 8.7 | .033 | 28. |
| .87 | .256 | 6 | 12.7 | .3 | 11.8 | .0019 | 29. |
| " | " | " | " | " | 13.3 | .00048 | 30. |
| 8.79 | .256 | 7 | 12.7 | .3 | 10.8 | .0048 | 31. |
| 1.45 | .250 | 10 | 13.0 | .5 | 8.8 | .030 | 32. |
| 2.98 | .246 | 7 | 13.3 | .4 | 14.3 | .00019 | 33. |
| 1.12 | .228 | 10 | 14.3 | .6 | 11.3 | .0030 | 34. |
| 1.15 | .225 | 6 | 14.5 | .4 | 11.2 | .0033 | 35. |
| 1.31 | .222 | 6 | 14.7 | .4 | 10.8 | .0048 | 36. |
| 1.87 | .214 | 14 | 15.2 | 1.0 | 14.2 | .00021 | 37. |
| " | " | " | " | " | 14.2 | .00021 | 38. |
| 1.14 | .212 | 6 | 15.4 | .4 | 11.6 | .0023 | 39. |
| .84 | .210 | 7 | 15.5 | .5 | 11.8 | .0019 | 40. |
| 6.09 | .210 | 6 | 15.5 | .4 | 9.9 | .11 | 41. |
| .78 | .209 | 10 | 15.6 | .7 | 10.2 | .0083 | 42. |
| .66 | .208 | 5 | 15.7 | .4 | 2.5 | 10. | 43. |
| 4.08 | .205 | 4 | 15.9 | .3 | 6.1 | .36 | 44. |
| " | " | " | " | " | 10.8 | .0048 | 45. |
| " | " | " | " | " | 12.3 | .0012 | 46. |
| .87 | .202 | 10 | 16.1 | .8 | 12.5 | .0010 | 47. |

tance $d$ expressed in light years (1 parsec = 3.26 light years) is equal to the relative probable error $r_p/p$ of the parallax. The absolute visual magnitude has been computed by the formula

$$M = m + 5 + 5 \log p$$

where $m$ is the apparent visual magnitude and $p$ is the parallax.

The error in $M$ is due mainly to the error in $m$ and may be appreciable, especially for some of the faint stars whose magnitudes are not always accurately known.

The absolute visual luminosities $L$ have been computed by the formula $\log L = 0.4\,(5 - M)$ for a value of $M = +5$ for the sun.

Membership in the list is uncertain at the lower end, especially where a star has only one determination. This uncertainty and the arbitrariness of the limiting parallax are well demonstrated by the exclusion of the interesting binary 70 Ophiuchi, whose final parallax value, based on many determinations, is $0''.199 \pm 0''.004$!

Of the former list, three stars (Nos. 10, 11, and 36) had to be dropped; thirteen stars have been added, thus resulting in a gain of ten items (excluding the sun) in the present list.

Ten objects of the present list are bright enough to be seen with the naked eye. There are four stars (Nos. 2, 8, 14, 43) whose intrinsic luminosity exceeds that of the sun, and two, possibly three stars (Nos. 4, 6, 26?) whose luminosity is less than 0.0001 times the sun's luminosity. Twenty-four of the 41 stars with known spectra (59%) are dwarf-M stars (ranging in $M$ from +16.6 to +8.7, or in $L$ from .000023 to .033); there are three white dwarfs (Nos. 9, 33, 45).

Twenty-two of the 47 stars (47%) are components of 8 double star and 2 triple star systems; some remarks about these follow.

*1, 2, 3.* $\alpha$ Centauri $A$ and $B$ form a binary system with a period of 80 years, and a semi-axis major of $17''.7$. The eccentricity of the orbit amounts to 0.52; the date of the next periastron passage is 1955.8. The sum of the masses is computed by the well-known formula

$$\mathcal{M}_A + \mathcal{M}_B = a^3/P^2p^3,$$

and is found to be twice the sun's mass; the individual masses are

$$\mathcal{M}_A = 1.1\ \odot,\ \mathcal{M}_B = 0.9\ \odot.$$

$\alpha$ Centauri $C$ is $2^\circ\ 11'$ distant from the center of mass of $A$ and $B$, which corresponds to a projected linear distance of over 10,000 astronomical units. The period of $C$ and $AB$ is of the order of a million years.

*8, 9.* The binary system Sirius $A$, $B$ has a period of 50 years and a semi-axis major of $7''.62$. The eccentricity of the orbit is 0.59 and the next periastron passage is in 1944.0. The sum of the masses is found to be 3.2 $\odot$, the individual masses are

$$\mathcal{M}_A = 2.2\ \odot,\ \mathcal{M}_B = 1.0\ \odot.$$

*14, 15.* The period of the Procyon system is 40.2 years, the semi-axis major is 4″.26. The eccentricity of the orbit is 0.31, the date of the last periastron passage was 1926.7. The masses are

$$\mathcal{M}_A = 1.4\ \odot,\ \mathcal{M}_B = 0.4\ \odot.$$

*16, 17.* The orbit of 61 Cygni is very uncertain, but the period is probably less than a thousand years. The present separation of the components is 26″.

*19, 20.* The orbit of Σ 2398 is indeterminate. A separation of somewhat over 17″ appears to have been reached in the beginning of the century. The present separation is 16″.4.

*21, 22.* The orbital motion in the Groombridge 34 system is very slow. The yearly increase in position angle is about 0°.06, that in distance about 0″.03. The present separation is 38″.

*25, 26.* The existence of a hitherto invisible companion to Ross 614 *A* is inferred from the variable proper motion of the system. The apparent magnitude of the *B*-companion is a mere guess.

*29, 30.* The period of the Krüger 60 system is 44.5 years, the semi-axis major is 2″.36. The eccentricity of the orbit is 0.41, the last periastron passage was in 1925.54. The masses are

$$\mathcal{M}_A = 0.26\ \odot,\ \mathcal{M}_B = 0.14\ \odot.$$

Krüger 60 *B* is one of the intrinsically faintest stars known; it is the star of smallest known mass.

*37, 38.* Wolf 424 *A-B* is a close double whose separation is 1″.1.

*44, 45, 46.* $o^2$ Eridani *B, C* form a binary system with a period of 248 years, and a semi-axis major of 6″.89. The eccentricity of the orbit is 0.40, the last periastron passage took place in 1848.9. The present separation is 6″. The sum of the masses is 0.6 ⊙ and the individual masses are probably something like

$$\mathcal{M}_B = 0.4\ \odot,\ \mathcal{M}_C = 0.2\ \odot.$$

The *B, C* system is 83″ distant from $o^2$ Eridani *A*, which corresponds to a projected distance of about 400 astronomical units; the relative proper motion indicates a period of the order of ten thousand years for the orbit of *BC* and *A*.

Several of the well-known features of stellar properties are clearly represented in this small but accurate sample of 47 objects. With the exception of the three white dwarfs, all the stars with known spectral type exhibit the "main sequence" relation between spectral type and ab-

TABLE II

| Abs. Vis. Mag. | No. of Stars |
|---|---|
| + 1.3 to + 2.4 | 1 |
| + 2.5 " + 4.9 | 3 |
| + 5.0 " + 7.4 | 6 |
| + 7.5 " + 9.9 | 6 |
| +10.0 " +12.4 | 17 |
| +12.5 " +14.9 | 11 |
| +15.0 " +16.6 | 3 |

solute magnitude. The frequency distribution of absolute magnitudes is, of course, affected by incompleteness of the data, but an increase up to at least about $M = +12.5$ (Table II) is indicated. The eleven available masses show the general relation between mass and luminosity, with the conspicuous exception of the companions of Sirius and Procyon.

Recent proper motion surveys have yielded a large number of stars, several of which undoubtedly have appreciable parallaxes. Furthermore, several stars of the present list may be double or have faint distant companions. A substantial increase of the present list, predominantly toward smaller luminosities, is therefore to be expected in the future.

SPROUL OBSERVATORY, SWARTHMORE COLLEGE,
SWARTHMORE, PENNSYLVANIA, 1940 MARCH 25.

# The Bands of Aristarchus

*By* DAVID P. BARCROFT

This treats of a little excursion taken while playing truant from a study of lunar surface changes and colors. The subject mentioned in the title, while important to the story, is by no means discussed at length. My excuse for offering the "results" to the public for inspection is simply the pleasure which they have occasioned me. No layman in his right mind would suppose that any of his activities in the astronomical field would be of much scientific importance, save possibly through accident; but things which are only interesting are for that reason alone not without value; and what has proved such to the average person will likely so appear to others.

Readers of this publication are generally familiar with the writings of Mr. Walter H. Haas relating to lunar colors. His article "Lunar Changes in the Crater Aristarchus," published in POPULAR ASTRONOMY, **48**, 135 (March, 1938), interested me a great deal; principally, perhaps, because the crater in question was one of the few features of the moon's surface whose location was known to me. Thereafter, whenever opportunity offered I made casual observations of this formation but after several months concluded that imperfections of my instruments or vision or both were such as to prevent my witnessing the markings and their changes which had been described.

However in 1939 another article was published by Mr. Haas in which he urged amateurs to take advantage of the opportunity which would be afforded by the lunar eclipse of October 27-28 of that year for a study of these changes under other than usual conditions, and he was rash enough to invite communications on the subject, a gesture which doubtless he has had occasion to regret many times since the offer was made.

In consequence I entered into a correspondence with him which has

continued, at least to my advantage, ever since. He took much time in steering me on to the right path, and as a result there is now plenty of detail apparent to me where before I could see nothing but a dazzling white spot.

But when he outlined for me an observing program which it was pretty evident would require two or three life spans such as I might reasonably hope to enjoy, for its completion, I began to take stock of the situation and cast about for some easier way of carrying on. Of course an approach by photography suggested itself at once, but my instructor, evidently realizing that his pupil was showing signs of shirking, gave me to understand gently but definitely that the correct method of following this line of endeavor was with drawing materials in hand, and at the eyepiece of the telescope. This was poor comfort to one whose artistic ability would be sorely taxed in an effort to create a stick horse on paper. And sometimes the nights are pretty cold, even in Central California.

Nevertheless I have followed instructions after a fashion, and while I was careful to keep my drawings from the critical sight of the small children with whom I come in occasional contact lest I suffer humiliation, I begin to feel rather proud of some of them in the light of what has since transpired.

I had been having considerable trouble in establishing the true course of the bands; it was difficult for me to orient the crater. The use of photographs seemed legitimate enough for assistance in overcoming this difficulty, so I took up with Mt. Wilson Observatory the matter of getting a portion of a photograph which shows the moon at 15 days, enlarged as much as could be done without destroying the definition of details which might be lurking in that blob of white which is Aristarchus about the time of full moon. The observatory told me that it was possible that the photograph in question could stand some further enlarging, so I placed the order. And while I was at it, I decided that I might just as well have a lantern slide.

The slides (two were made) reached me first. I made a quick trip to Fresno where I have a resourceful friend and associate named Landquist, who in anticipation of my needs had borrowed a projector for me and had made a screen by painting one of his window shades white. As my eyes adapted themselves to the projected image, it occurred to me that I was likely seeing more detail in this crater at this period of the lunation than had ever been witnessed before—that is, unless the people in the observatories engage in such amusement and do not tell anyone about it.

The major axis of the projected image of the white part of the crater measured about two inches. When my associate and I stood at the best distance from the screen, we were able to discern at least eight objects within the crater and on its walls, which I shall cautiously designate as bands, portions of bands, or features in the nature of dark bands. Here-

after "bands" should be unobjectionable. Two of these appeared to form a fork, having a common point of origin at the foot of the crater wall, and diverging as they progressed toward the top. There may be some similarity between these and the double band in the crater Aristillus which was discovered by Professor W. H. Pickering, and was the subject of some articles by him several years ago. There were also a number of white bands. If the size of the image could be reduced to about an inch or so, it is possible that the definition which was good with the large image would be even better. We could not do this with the machine we were using.

S

E

ARISTARCHUS, HERODOTUS, AND SURROUNDING REGION

Not knowing how much detail will disappear through reproducing, no discussion of the photograph is attempted. This photograph has served a double purpose. It should not be at all difficult in the future to indicate the position of these bands with fair accuracy. And as I readily recognized some of the bands and other features appearing in the image through their shapes, it is immensely satisfying to know that I have no

visual disorders other than those resulting from natural wear and tear, and I feel entitled to assume that any observations carefully made in the future will be reasonably accurate and free from a large amount of subjective error. Nor do my drawings now seem so bad, the photograph having partially confirmed them.

Lest any who might be interested in this subject lose heart on account of my possibly ill-advised remark as to what Mr. Haas considers a fair amount of work, I will say that the study of colors and changes is a good deal like a game of tennis. You can make it as easy or as intense as you desire.

And those amateurs, especially amateur telescope makers, who think that lunar observations are not a sufficiently rigorous test of the quality of a mirror are in my opinion badly deceived. I have found out more facts concerning the peculiarities of the various small reflectors which I use, and about observing in general, since I embarked on this lunar program than I was ever able to pick up before.

With the pictures on hand I commenced to wonder whether I might not be able to look into the depths of this crater by means of a stereoscope. This seemed to have its problems. I knew that to get the effect of depth and perspective it was usual to make double photographs, the camera being moved a short distance between exposures. I later learned that in the case of the moon advantage may be taken of the libration in obtaining photographs suitable for stereoscopic use.

Meantime I had seen advertised an instrument which was said to produce a stereoscopic effect from a single picture. I acquired one of these, and after setting up the photograph and experimenting with the device for a few seconds, suddenly, Aristarchus and its environs flashed into weird relief. It would be futile to attempt to describe what the appearance was to me. With the quality or element of depth added, the dark area just to the north of the white part of the crater appears to be considerably higher than the rest of the walls, and it seems to project from the white portion. It reminds me of the manner in which iron filings cling to a magnet. The formation on the east side of this crater appears to me much as a huge mountain of coal with some white substance sprinkled over it, and it seems to be sufficiently high toward the south to partially obscure the north wall of Herodotus. Possibly this is rather on account of shadow. Of course I do not claim that the actual color of this mountain is black. It must be borne in mind that I was examining a black and white photograph. Likely there are effects resulting from the grain of the negative, and no pretense is made that anything approaching accuracy can be obtained through the simple device, which I was using.

There appears to be a definite "down grade" from the south of Aristarchus toward the west and north of Herodotus. Other "bands" are noticeable in a small crater southwest of Aristarchus, and possibly in a very small one just east of Herodotus.

A slide and photograph have gone on to Mr. Haas, and it is my hope that they will interest him to the extent that he will forget to castigate his errant disciple. The cost of these enlargements is $1.00 each, and of the "stereoscope," between $2.00 and $3.00. The enjoyment which I have received from such a small outlay makes me think that it is about as good an investment as I ever made. I shall no longer have to rely absolutely on those authorities and heroes of my childhood, Messrs. Barbicaine, Arden and Nicholl, but I now feel prepared by the aid of recent science, invoked while seated comfortably before my office desk, to check the accuracy of their findings made while on that strenuous expedition conceived and successfully consummated under the able direction of Mr. Verne.

MADERA, CALIFORNIA, FEBRUARY 12, 1940.

# The Orbit of the Pultusk Meteor

By C. C. WYLIE

## ARE METEORITES FROM OUR SOLAR SYSTEM?

The question whether fireballs dropping meteorites have been members of the solar system (have been travelling in elliptical orbits), or have come in from the distances of the stars (have been travelling in hyperbolic orbits), is one of great interest to astronomers. Meteorites are the only extra-terrestrial objects we can examine in our laboratories. Chemists can determine their composition, and, by modern methods, physicists can determine their approximate age. Composition is not greatly different from terrestrial rocks, excepting that unoxidized nickel-iron is present, and the age is not greatly different from the oldest terrestrial rocks. If meteorites have been members of the solar system, astronomers must provide for them in their hypotheses of the origin of the solar system. If they have come in from outside of the solar system, we have the interesting implication that our universe is not appreciably older than the earth itself.

## THE PULTUSK METEOR

Among the meteorites most commonly referred to as from outside our solar system are those of the Pultusk fall of January 30, 1868. In *Harvard Reprint* No. 84, (POPULAR ASTRONOMY, **41**, 76, February, 1933) Professor Öpik[1] refers to this fall, and makes the statement "the hyperbolic velocity of this meteorite stands practically beyond question, as may be inferred from the careful discussion by Galle." Dr. Galle was one of the leading astronomers of that day, the man who discovered the planet Neptune on September 23, 1846.

[1] See also Hoffmeister, "Die Meteore," pp. 8, 26; Farrington, "Meteorites," p. 213.

Because of an inquiry from one of the physicists working on the age of the Pultusk and other meteorites, and because of the references to the orbit of this meteor as hyperbolic, we have undertaken to calculate its orbit. Unfortunately for the purposes of this study, we were unable to secure a copy of Dr. Galle's original paper which appeared in *Jahresberichte der Schlesischen Gesellschaft für vaterländische Kultur in Breslau* for March, 1868. We do have references to his paper, however, which give the more important results. Dr. Öpik's paper, referred to above, gives a number of results and considerable useful information. The fundamental facts of the path are listed in the von Niessl-Hoffmeister "Catalogue of the Paths of 611 Great Meteors," published in Vol. 100 of the *Denkschriften Akademie Der Wissenschaften In Wien.* Another reference to the path as determined by Galle is given in Haedinger's article in the *London Philosophical Magazine,* **37**, 259, 1869.

### Galle's Path for the Pultusk Meteor

The height of the endpoint is given by Galle as 42 kilometers (26 miles). The height of appearance is given as 278 kilometers (173 miles), but a lower height, 171 kilometers (106 miles), is used in calculating the velocity. The duration is given as 6.7 seconds, this being the average of 26 estimates. The observed velocity is given as 27.5 kilometers (17 miles) per second. The altitude of the apparent radiant is given as 44°, and the azimuth as 60° from the south point. The right ascension is given as 13°.5, and the declination as +19°.

### Psychological Errors in the Path

The results of Galle on this meteor are about what careful astronomers have obtained from reports of the general public, from his own time to the present. There is no reason for doubting that these figures are the result of correct calculations from the reports of intelligent persons who had a good view of the meteor.

Modern work, however, has shown that reports such as those on which Dr. Galle undoubtedly had to base his path contain important psychological errors. The following paragraphs list some of the evidence.

Numerous comparisons have been made using measures on the apparent path of a meteor as pointed out by persons in the same community. The person who sees the entire path in a limited region of sky marked by familiar objects usually points out a path only a fraction of the length pointed out by his friend who has a "splendid view," with the entire path in open sky. (See *Contribution of the University of Iowa Observatory,* No. 9, p. 289; P. A., **47**, 206.)

The von Niessl-Hoffmeister Catalogue, previously referred to, is quoted by those who accept highly hyperbolic velocities for meteors. Seventy-nine per cent of the heliocentric velocities in this catalogue are hyperbolic.

A statistical study of the relations between height of appearance, length of path, geocentric velocity, and heliocentric velocity was made at

Iowa (*Contribution* No. 8, pp. 258-260; P. A., **45**, 209). From these relations several tests could be made as to whether the high heliocentric velocities were real or fictitious. All tests indicated that they were fictitious, due to a fictitious extension of the length of path, so the catalogue is evidence against, rather than for, the reality of the hyperbolic velocities.

A second statistical study using this catalogue was made by Dr. Fletcher Watson, of Harvard. (See *Proceedings of the American Philosophical Society*, Vol. 81, No. 4, September, 1939, *Harvard Reprint*, No. 179.) From a study of the radiants, Dr. Watson found that "the great majority of the bodies listed in the catalogue were moving in direct orbits of low inclination," and also that "it is probable that the velocities in the von Niessl-Hoffmeister *Katalog* are too great and that the bodies listed there were permanent members of the solar system." This is equivalent to saying that it is probable that the high velocities, often found by astronomers who use the reports of the general public on meteors, are not real.

The acceptance of the very great heights of appearance for the Pultusk and other meteors dropping meteorites involves the assumption that the height of appearance of spectacular fireballs is several times that for shooting stars. But the Iowa heights for the appearance of spectacular meteors, as published in *Contribution* No. 6, average lower than the Iowa heights for appearance of shooting stars, as published in *Contribution* No. 4. The British results published in *The Observatory*, Volumes 45-55, show a lower beginning height for spectacular detonating meteors of magnitude about —18 than for shooting stars of magnitude zero and +2. (See *Contribution* No. 8, pp. 263-264; P. A., **45**, 269.) The von Niessl-Hoffmeister Catalogue includes several shooting stars of magnitude about zero. The beginning heights for these are higher than for the spectacular meteors of magnitude —18, or thereabouts, included in the same catalogue. (See *Contribution* No. 8, pp. 263-264.)

These references show that where the same workers have published results for both shooting stars and detonating meteors, the heights of appearance have been found lower for the detonating meteors. Results from continental Europe, England, and America agree on this point. These results indicate also that there is little change in the height of appearance from shooting stars of magnitude zero to the most spectacular detonating meteors. Hence, reports which indicate extraordinary heights of appearance for spectacular meteors must be erroneous, and hyperbolic velocities based on such reports must be erroneous.

## Adopting Figures for the Path

With these facts in mind, let us now examine Galle's results, and adopt figures for the path through the atmosphere.

Considering that Galle had a great number of reports, it seems that his figures for the apparent radiant should be approximately correct.

There is no way to check on their accuracy, so they are adopted as he gave them. They are altitude 44°, azimuth 60° from the south point, right ascension 13°.5, and declination +19°.

The height of the end point is affected by two psychological errors, one of which tends to make it too low, and the other tends to make it too high. Galle's figure may be a little high, but there is no way in which we can improve it without the original reports. Let us therefore adopt Galle's figure, which is 42 kilometers (26 miles).

The duration is given by Galle as 6.7 seconds. This is the average of the 26 estimates he used. Öpik, on a re-examination of the estimates, cut the list to 13, ranging from 2.5 seconds to 8 seconds, the average being 4.6 seconds. Experience shows that unless an observer is interviewed very soon after the fall of the meteor, his estimate of the duration tends to be too small. In other words, the average of the estimates received from educated people tends to be a little smaller than estimates received very promptly, or durations based on the re-enactment of the scene. From this and from the fact that Galle adopted a larger figure, it appears that Öpik's figure of 4.6 seconds may be a little small, but we are adopting it rather than the original figure of Galle.

As indicated in an earlier paragraph, if the figure for the height of the end point is in error, it probably is too high. This would tend to make the path too short and the velocity too low. If Öpik's figure for the duration is in error, it probably is too small. This would tend to make the velocity too high. Possible errors in our adopted figures for height of the end point, and duration, should tend to counteract, or eliminate one another.

The height of appearance, as we have said, was given as 278 kilometers (173 miles), but a lower height, 171 kilometers (106 miles), was used in calculating the velocity. This height is affected by two psychological errors, both of which tend to make it too high. Reports on almost any spectacular meteor include some which place the beginning at a very great, or even an infinite, height. Let us compare Galle's figures with others for detonating meteors.

For the brightest detonating and stone dropping meteors of the von Niessl-Hoffmeister Catalogue the median height of appearance is about 67 miles, but the studies previously quoted show this is too high. For the brightest detonating meteors reported in *The Observatory*, the median height of appearance is about 57 miles. For the Iowa paths of detonating meteors, based on measures from interviews, the height of appearance is about 50 miles.

Galle's figure for height of appearance is obviously impossible, but without the original reports there is no way in which we can eliminate the psychological errors. Indeed we probably could not, even with the reports at hand. The beginning height must have been, however, about the same as for similar meteors in modern times, that is about 50 miles.

The problem is simplified by the fact that this height varies little from bright shooting stars to the spectacular detonating meteors. Let us adopt the figure which was found for the meteor which dropped the world's record stone near Paragould, Arkansas. This figure, which is above the average of those published in *Contribution* No. 6, is 52 miles.

Using the adopted figures for height of appearance, height of disappearance, angle of fall, and duration, the apparent velocity was calculated. It was found to be 8.1 miles per second, which is a low velocity, in agreement with reports that the meteor was travelling very slowly just before disappearance.

### Adopted Path

| | |
|---|---|
| Height of appearance | 52 miles |
| Height of end point | 26 miles |
| Length of path | 37.4 miles |
| Azimuth of apparent radiant | 60° from south |
| Altitude of apparent radiant | 44° |
| Right ascension of apparent radiant | 13ʰ5 |
| Declination of apparent radiant | +19° |
| Apparent velocity | 8.1 miles |

### Corrected Radiants and Velocities

Correcting the apparent radiant and apparent velocity, the geocentric radiant and velocity were obtained. Correcting these for the earth's motion, the heliocentric radiant and velocity were obtained. These are as follows:

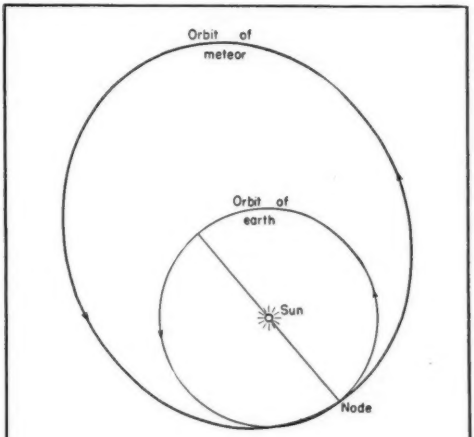
| | |
|---|---|
| Right ascension of geocentric radiant | 4ʰ6 |
| Declination of geocentric radiant | + 6ʰ7 |
| Geocentric velocity | 4.2 miles |
| Right ascension of heliocentric radiant | 31ʰ5 |
| Declination of heliocentric radiant | +13ʰ6 |
| Heliocentric velocity | 22.4 miles |

### The Orbit

From the coördinates of the earth, the heliocentric radiant and the heliocentric velocity, the orbit of the meteor about the sun was computed, using the method given in *Contribution of the University of Iowa Observatory*, No. 9. The following are the elements:

$$a = 1.78$$
$$e = 0.45$$
$$\omega = 159°9$$
$$\Omega = 310°3$$
$$i = 0°8$$
$$P = 2.37 \text{ years}$$

It will be noticed that the orbit is very similar to those which have been determined previously at Iowa for spectacular fireballs, detonating fireballs, and fireballs dropping meteorites. The eccentricity, period, and inclination are all less than for the average short-period comet. For this meteor the inclination is exceedingly small. The drawing shows the orbit of the meteor projected on the plane of the orbit of the earth.




THE ORBIT OF THE PULTUSK METEOR
(JANUARY 30, 1868)


## Summary

The available information indicates that with one exception Galle's figures for the Pultusk meteor should be close to the truth. The exception is the height of appearance which is much too high. Since there is little variation in the height of appearance for fireballs varying greatly in size and brightness, a height based on modern measures was adopted for the Pultusk meteor.

Using this adopted height of appearance the velocity was determined, and following this the elements of the orbit about the sun. It was found that, instead of being hyperbolic, the Pultusk meteor was a quite regular member of our solar system, the orbit having a relatively small period, eccentricity, and inclination.


The calculations in this paper have been checked by J. W. Kitchens, former Research Assistant, and J. F. Foster, Jr., present Research Assistant.

University of Iowa Observatory, April 18, 1940

# The Modification of Solar Climates by Meteorological Influences

By EDGAR W. WOOLARD

The general distribution of temperature over the earth leading to the division of the earth's surface into the Torrid, Temperate, and Frigid Zones, and the annual cycle of the seasons are phenomena which belong both to astronomy and to meteorology, and are discussed in all textbooks and treatises on either subject.

From the relation of the seasons to the apparent annual motion of the sun (even to the extent of the reversal of the seasons in the two hemispheres), and from the correspondence of the thermal belts of the earth to the aspects of the celestial sphere at different latitudes, it is clear that both phenomena are fundamentally controlled by the astronomical relations which determine the relative amounts of energy received from the sun on different parts of the earth. It is equally clear, however, from several facts of common experience, that the astronomical relations alone do not completely account for the phenomena; the distribution of solar radiation over the surface of the earth after transmission through the atmosphere is only in a general way similar to the distribution determined by astronomical circumstances alone, and moreover the amount of solar radiation received at a given place is not the only factor determining the temperature and the temperature variations at that locality: Different regions of the earth at the same latitude may have widely different climates, as, *e.g.*, in the case of Labrador and the British Isles. The warmest period of summer does not in general occur at the time of the longest days, nor the coldest period of the winter at the time of the shortest days; and the amount of the lag varies irregularly from place to place. Again, on February 9, 1934, the temperature at Washington, D. C., dropped to —6°.5 Fahr., the lowest that had been recorded there in 22 years; yet on that same day, the intensity of the solar radiation that reached the ground attained the highest value ever observed at Washington at any time during 20 years of measurements. Further, the weather map of the North American continent for the morning of December 12, 1934, showed a temperature of 30° Fahr. extending continuously from southern Florida northwestward across the entire United States and Canadian Northwest up into the Yukon.

These modifications of the conditions that would result from exclusively astronomical causes originate in effects superimposed jointly by a number of terrestrial influences, among which the action of the atmosphere on radiant energy passing through it, and the transport of heat by winds and ocean currents are the most important. The explanations of the phenomena are well known, and are given in most textbooks; the purpose of the present paper is to present a few relevant data which

have not been so widely disseminated among astronomers as among meteorologists, and which may be of especial interest to those engaged in teaching elementary astronomy.

The rate at which solar radiant energy reaches a surface perpendicular to the sun's rays outside the earth's atmosphere at the earth's mean distance from the sun[1] is $I_0 = 1.94$ gram calories per square centimeter per minute, according to the determinations of the Astrophysical Observatory of the Smithsonian Institution; this quantity is known as the solar constant. Every minute, therefore, the earth intercepts an amount of energy from the sun equal to

$$\pi R^2 \frac{I_0}{r^2}$$

where $R$ is the radius of the earth and $r$ its distance from the sun. This energy falls on a hemispherical surface, however, and hence is unequally distributed over the outer atmosphere of the earth because of the varying inclination of this surface to the rays of the sun; while during its passage through the atmosphere, it is continually depleted through scattering and absorption by the air and by the dust particles and clouds in the atmosphere. The distribution of solar radiant energy at the surface of the earth, as determined jointly by the astronomical relations of the sun and the earth and by the physical state of the atmosphere, is therefore highly irregular and variable.

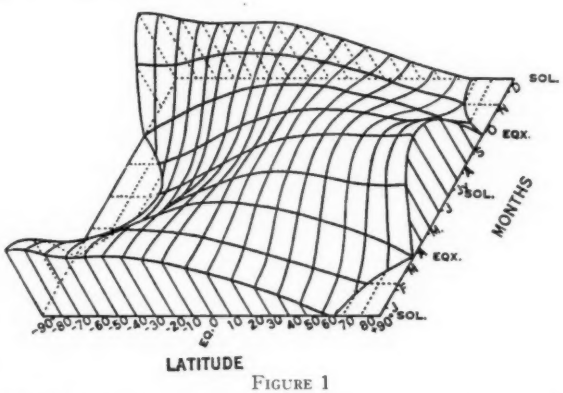



FIGURE 1

Relative daily totals of solar radiant energy incident on a horiontal surface at the outer limit of the atmosphere, by latitude and time of year; prepared by W. M. Davis. *Cf.* Table 1. The maximum value occurs at the south pole on the day of the winter solstice.

The calculation of the rate at which energy is received on a horizontal surface at the outer limits of the appreciable atmosphere is a simple

[1] *I.e.*, at a distance equal to the semi-major axis of the earth's orbit.

problem in elementary mathematical astronomy.[2] The distribution of the relative total amounts per day by latitude and time of year is shown graphically in Figure 1, published many years ago by W. M. Davis in his "Elementary Meteorology"; a few representative numerical values are given in Table 1. The calculations may be made either from a finite

TABLE 1

*Total amount of solar radiant energy received during one day on a horizontal surface at the outer limit of the atmosphere, in terms of the amount received at the equator on the day of the vernal equinox; and annual totals at different latitudes.*

| Date \ Latitude | 0° | +20° | +40° | +60° | +90° | −90° |
|---|---|---|---|---|---|---|
| Vernal Equinox | 1.000 | 0.940 | 0.766 | 0.500 | 0.000 | 0.000 |
| Summer Solstice | 0.882 | 1.044 | 1.107 | 1.093 | 1.201 | 0.000 |
| Autumnal Equinox | 0.987 | 0.927 | 0.756 | 0.494 | 0.000 | 0.000 |
| Winter Solstice | 0.941 | 0.676 | 0.357 | 0.056 | 0.000 | 1.283 |
| Annual total | 348000 | 329000 | 275000 | 198000 | 144000 | 144000 |

The unit is about 894 gram calories per square centimeter.

formula in terms of the sun's declination, or from a trigonometric series in the sun's mean longitude.

No accurate calculation of the transmission by the atmosphere and of the rate at which solar radiant energy is received on the surface of the earth is in general practicable; reliable values can be determined only by actual observations at each given locality. As the radiation passes through the atmosphere, part of it is scattered in all directions by the molecules of the atmospheric gases, including water vapor, and by the dust particles in the air, while another part is selectively absorbed, principally by water vapor, carbon dioxide, and (in the very high atmosphere) ozone; the remainder, except as intercepted and reflected by clouds, reaches the surface of the earth where it is partly absorbed and partly reflected. The molecular scattering by the gases of the atmosphere is the principal cause of the blue color of the sky; scattering by very fine dust also contributes, but, contrary to the statements in some textbooks, is an unimportant factor, while the effect of the larger dust particles is to dilute the blue with white. The depletion of the solar beam through molecular scattering by the atmospheric gases exclusive of water vapor can be accurately computed from physical theory; but any calculation of the other losses is subject to considerable uncertainty, especially since the distribution of water vapor and dust throughout the atmosphere is not known with any completeness. The radiant energy received on the average over a given region can be estimated from climatological data if radiation measurements have been made at a few well-distributed sta-

[2] See A. Angor, Recherches théoriques sur la distribution de la chaleur à la surface du globe, *Annales du Bureau Central Météorologique de France,* Année 1882-1883, Pt. I; Wm. Ferrel, Temperature of the Atmosphere and the Earth's Surface, *Professional Papers of the Signal Service* No. XIII, 1884; M. Milankovitch, *Théorie mathématique des phénomènes thermiques produits par la radiation solaire,* Paris, 1920; W. J. Humphreys, "Physics of the Air," 2 ed. pp. 78-84, New York, 1929.

tions, but at best the results are only approximations which may be widely in error.

On the average, for the earth as a whole, about 40 per cent of the solar radiation incident at the outer limit of the atmosphere is scattered or reflected directly back to interplanetary space from the air, clouds, and the earth's surface; the remainder is absorbed, mostly in the lower atmosphere and at the surface of the earth. At the same time, of course, the earth and its atmosphere both are continually emitting long wave-length radiation. In the long run, the earth as a whole returns to space practically the same amount of radiant energy that it receives from the sun.

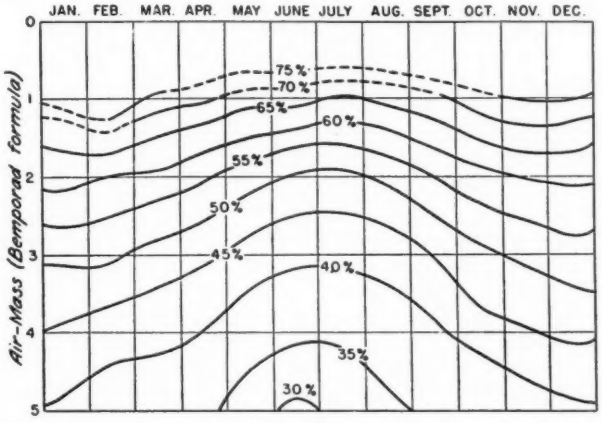



FIGURE 2

Average intensities of direct solar radiation on a surface perpendicular to the sun's rays at Washington, D. C., by time of year and altitude of the sun; the "air-mass" is approximately equal to the secant of the zenith distance. The values have been reduced to mean solar distance, and expressed as percentages of the solar constant. Prepared by I. R. Hand, from observational data covering 22 years.

The solar radiant energy incident on the surface of the earth comprises both the direct rays from the sun that have penetrated the atmosphere and the diffuse scattered light from the sky; the latter is a considerable portion of the total (the whole of it when the sky is cloudy). The fundamental role of this energy in a wide range of natural phenomena, many of which are of great practical importance, has led to the regular measurement of solar and sky radiation, usually by meteorological or geophysical institutions, at a large number of places distributed over the earth. In the United States, the Weather Bureau has been making such observations since 1901. At the present time, the intensity of the total radiation from sun and sky on a horizontal surface is continuously recorded (from sunrise to sunset) by self-registering instruments at 8 stations maintained by the Weather Bureau and at 9 coöperating stations

maintained by other institutions; while pyrheliometric measurements of the intensity of direct solar radiation on a surface perpendicular to the solar rays are made at frequent intervals on clear days at 3 Weather Bureau stations and one coöperating station. The current data are published regularly in the *Monthly Weather Review;* and a complete summary of the methods and results to date has recently been issued.[3]

The depletion of the direct solar beam by the atmosphere is illustrated in Figure 2, which shows the average intensities of direct solar radiation on a surface perpendicular to the sun's rays at Washington, D. C., expressed in percentages of the solar constant, at different times of the year and different altitudes of the sun; the so-called "air mass" is approximately equal to the secant of the zenith distance. *E.g.*, at Washington, when the zenith distance of the sun is approximately 60° (sec 60° = 2), on a clear day in February about 60 per cent of the solar radiation reaches the surface of the earth on the average, but in July less than 50 per cent gets through.

The form of the curves shows that on a clear day the atmosphere is least transparent to solar radiation during summer, on the average. However, because of the greater duration of sunshine and the greater average altitude of the sun, the total quantity of radiant energy received at the surface of the earth is greater during summer, especially when account is taken of the solar radiation received indirectly from the sky. The dashed curve in Figure 3 shows the average total quantity of radiant energy received each day throughout the year on a horizontal surface at Washington, from both sun and sky; the superimposed irregular curve shows the values during the one particular year 1925. The uppermost smooth curve gives the daily totals of radiation on a horizontal surface at the outer limit of the atmosphere over the latitude of Washington.

The lower smooth solid curve in Figure 3 shows the average daily temperatures at Washington. The lag of the times of highest and lowest temperatures behind the times of greatest and least supply of heat (at either the surface of the earth or the outer limit of the atmosphere) is quite evident. Astronomical textbooks are usually rather indefinite as to the amount of this lag, though many of them give August 1 and February 1 as the approximate dates of highest and lowest temperatures; very few emphasize the dependence of the lag on local circumstances, and the wide variations from place to place. "Normal" daily temperatures, obtained by averaging the daily temperatures observed over a long period of years, are now available for a large number of places on the earth; but comparatively few studies seem to have been made of the relation of the annual maxima and minima to the times of the solstices.[4] In general, in

[3] Irving F. Hand. "Review of United States Weather Bureau Solar Radiation Investigations." *Monthly Weather Review*, 65:415-441, 1937 Dec.

[4] See Hann-Süring, "Lehrbuch der Meteorologie," 5te aufl., 2te Lief., Leipzig, 1937, pp. 148-150.

temperate latitudes, the lag averages about 25 days in regions having a continental climate, but is nearly two months in regions having a marine climate; in high latitudes, the lag averages about a month and a half. At particular localities, however, the retardation may differ considerably from these averages and may not be the same for the maximum as for the minimum temperature. Altitude above sea level is of course one of the important factors.

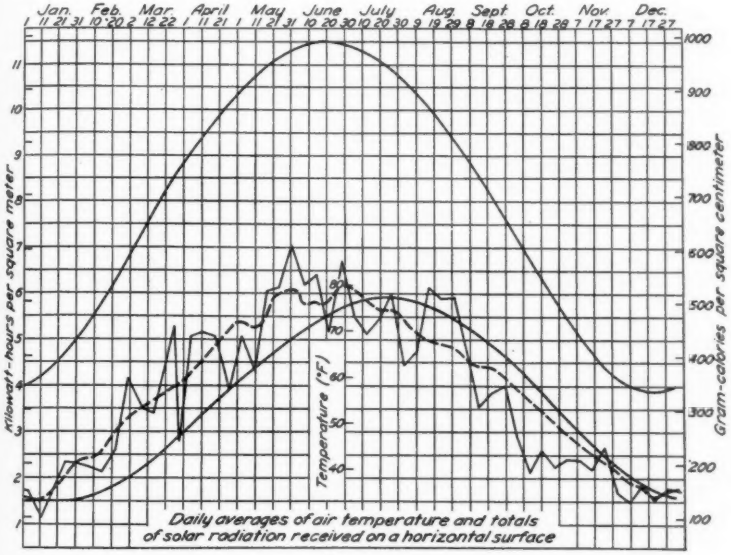

Jan. Feb. Mar. April May June July Aug. Sept. Oct. Nov. Dec.
Kilowatt-hours per square meter
Gram-calories per square centimeter
Temperature (°F)
Daily averages of air temperature and totals of solar radiation received on a horizontal surface

FIGURE 3

Upper smooth curve: daily totals of solar radiant energy incident on a horizontal surface at the outer limit of the atmosphere, latitude of Washington, D. C. Dashed curve: average daily totals of radiant energy from both sun and sky on a horizontal surface at Washington, D. C., determined from observational data covering 22 years; the superimposed irregular curve shows the *observed amounts during a single year* (1925). Lower smooth curve: Normal daily temperatures, Washington, D. C. Prepared by I. F. Hand and H. H. Kimball.

Recently, the intervals from the solstices to the dates of highest and lowest normal daily temperatures throughout the United Sates have been very completely determined,[5] and are shown by Figures 4 and 5. These charts indicate the great influence exerted by physiographic and meteorological circumstances in determining the conditions that result from the supply of solar radiant energy as fixed by exclusively astro-

[5] E. H. Bowie, "Relation of the extremes of normal daily temperature to the solstices," *Monthly Weather Review*, 63:248-250, 1935.

nomical relations.

The amount of the lag varies over the United States from less than 10 days to as much as 100 days. An effect of latitude on the time of lowest temperature is conspicuous in Figure 5, but is lacking in Figure 4 except in the Rocky Mountain and Plateau regions. The extent to which the climate of a given region is influenced by an adjacent ocean or ocean current depends upon the prevailing wind direction and the nature of the topography. Thus, the retardation of the highest temperature is considerably increased along the Gulf Coast by the prevailing onshore winds during the summer, because the ocean waters warm up comparatively

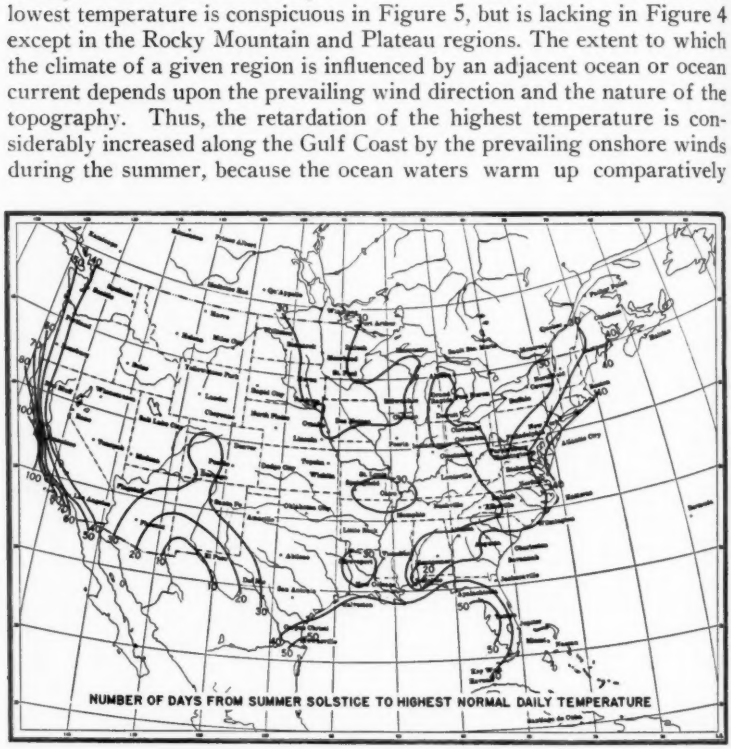



FIGURE 4

slowly; but only a slight effect is exerted on the time of lowest temperature, because of the difference in the prevailing wind direction during the winter. The Atlantic Ocean has a distinct effect on the time of highest temperature along the northern Atlantic Coast, but less of an effect on the lowest temperature. Even the Great Lakes seem to exert some influence. However, it is the Pacific Coast region which shows the great magnitude of the effects that can be produced by a favorable combination of circumstances; at San Francisco the time of highest normal temperature is delayed 100 days beyond the summer solstice by prevailing winds from off the cool ocean surface, while less than 100 miles inland, at Sacramento, the retardation is only 37 days.

A comparison of general climatic conditions in the northern and the

southern hemispheres of the earth, especially with respect to the temperatures of corresponding seasons, provides further illustrations of the effect of physiographic influences in modifying or outweighing the results of astronomical circumstances: Some textbooks of astronomy state unequivocally that in the southern hemisphere the summers are warmer (though shorter) and the winters colder (and longer), and hence the contrast between the seasons greater, than in the northern hemisphere, because the northern winter and the southern summer occur while the earth is near perihelion (and moving most rapidly). Some textbooks are careful to add the qualification that the actual differences are not great,

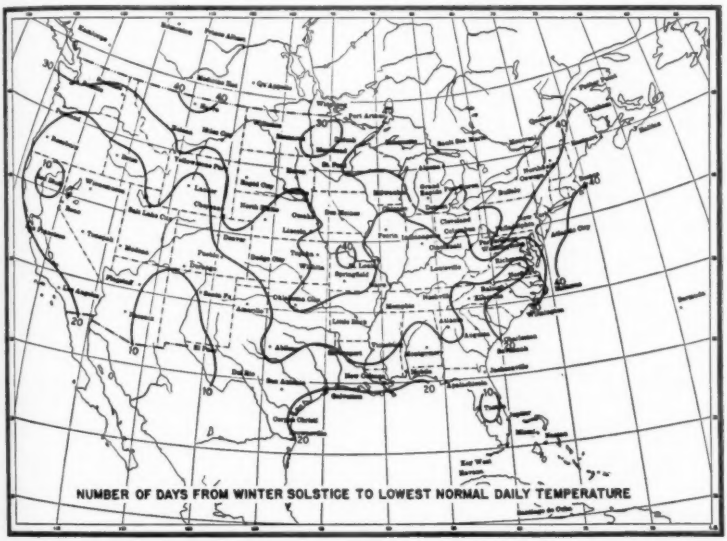



FIGURE 5

because of the moderating influence exerted by the larger extent of oceanic areas in the southern hemisphere; while other texts are indefinite as to the actually existent conditions, merely stating that there is at least a tendency to such differences and that they would occur were it not for the larger proportion of water, and other physiographic circumstances, in the southern hemisphere. We may of course say, as a few books do, that the seasonal variations in the northern hemisphere as a whole are less extreme, and those in the southern hemisphere more extreme, than they would be were perihelion and aphelion interchanged, other things remaining the same; but it does not necessarily follow that the variations in the southern hemisphere are more extreme than those in the northern hemisphere. As a matter of fact, the actual conditions are

exactly the reverse. Large differences are not to be expected in any case, since the total annual variation in the intensity of the solar radiation intercepted by the earth is only about 7 per cent, while the difference in the length of the seasons is only 7 days; and the effects of these factors are more than offset by physiographic influences.

The average temperatures of each hemisphere as a whole and of the entire earth, for January, July, and the year, so far as they can be ascertained from available meteorological data,[6] are shown in Table 2. It will

TABLE 2

*Comparative seasonal and annual temperatures of the northern and southern hemispheres and of the earth as a whole, as indicated by averages for January, July, and the year, in Centigrade degrees.*

| | Year | Summer | Winter | Difference |
|---|---|---|---|---|
| Northern Hemisphere | 15.2 | 22.4 | 8.1 | 14.3 |
| Southern Hemisphere | 13.3 | 17.0 | 9.7 | 7.3 |
| Difference | 1.9 | 5.4 | —1.6 | .... |
| Earth | 14.3 | 16.0(July) | 12.6(Jan.) | 3.4 |

be noted that the contrast between seasonal temperatures is less in the southern hemisphere than in the northern; and that the average temperature of the southern hemisphere during the southern summer is lower than the average temperature of the northern hemisphere during the northern summer, while the southern winter is warmer than the northern winter.

It is easily shown that the total amount of solar radiant energy intercepted annually is the same in the two hemispheres. However, on the average for the year, the southern hemisphere as a whole is cooler than the northern, even though its average elevation above sea level is 100 meters less. Moreover, the annual average temperatures of the torrid zone and of the temperate zone separately are each lower in the southern hemisphere than in the northern; and up to latitude 75°, the southern hemisphere averages cooler in all four seasons than the northern hemisphere up to the corresponding latitude.

The total amount of solar radiant energy intercepted by the earth as a whole while the radius vector describes a given angle is always the same; in particular, the same amount of energy is intercepted from vernal equinox to autumnal equinox as from autumnal to vernal, although these two equal amounts are distributed over unequal times. However, since the comparatively cold northern winter coincides with the comparatively cool southern summer, the average temperature of the earth as a whole is lower near perihelion (though the intercepted solar radiation is then most intense).

WEATHER BUREAU, WASHINGTON, D. C.

[6] Hann-Süring, "Lehrbuch der Meteorologie," 5te aufl., 2te Lief, Leipzig, 1937, pp. 180-183.

# Planet Notes for July and August, 1940

By R. S. ZUG

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Standard Time, 6 hours, etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac.*

*Sun.* The sun will be situated in the constellation Gemini until July 19, at which time it enters the constellation Cancer. On August 9 it enters the constellation Leo, where it remains for the duration of that month. The earth will be at the aphelion point of its orbit on July 4.

*Moon.* Phenomena of the moon will occur as follows:

| | | | h | m |
|---|---|---|---|---|
| New Moon | July | 5 | 11 | 28 |
| First Quarter | | 12 | 6 | 35 |
| Full Moon | | 19 | 9 | 55 |
| Last Quarter | | 27 | 11 | 29 |
| New Moon | Aug. | 3 | 20 | 9 |
| First Quarter | | 10 | 12 | 0 |
| Full Moon | | 17 | 23 | 2 |
| Last Quarter | | 26 | 3 | 33 |
| Perigee | July | 9 | 19 | |
| Apogee | | 25 | 5 | |
| Perigee | Aug. | 6 | 3 | |
| Apogee | | 21 | 22 | |

*Mercury.* Mercury will be an evening star during the first weeks of July, but too close to the sun to be easily seen after sundown. It reaches inferior conjunction with the sun on July 22, after which, as a morning star, its elongation from the sun increases, until on August 10 a greatest elongation of 18° 57′ is attained. The stellar magnitude of the planet on the latter date will be —0.2.

*Venus.* Venus becomes a morning star on June 26. Its elongation from the sun increases rapidly during July, and, after the middle of the month, it should be an easy object to locate in the eastern sky just before sunrise. The planet reaches its greatest brilliance as a morning star on August 2, when its stellar magnitude will be —4.2. Greatest elongation will not be attained until September 5. Numerical data of interest to observers will be found on page 8 of the January issue of POPULAR ASTRONOMY.

An occultation of Venus will occur on July 31, observable in the central and western portions of North America, between the limiting parallels of latitude 12° N. to 72° N. At longitude 91° W. and latitude 40° N., the times of immersion and emersion are, respectively, 4:17 P.M. and 4:57 P.M. (Central Standard Time). At longitude 120° W. and 36° N. the corresponding times are 2:16 P.M. and 3:17 P.M. (Pacific Standard Time). Instructions for computing the times of immersion and emersion for intermediate points are listed under "Occultation Predictions," in this issue of POPULAR ASTRONOMY.

*Mars.* Mars will be inconspicuous in the evening sky during July and August. The planet will reach superior conjunction with the sun on August 30. A conjunction with the planet Mercury will occur on July 10, $0^h$, with Mercury situated 4° 24′ to the south of Mars.

*Jupiter.* Jupiter will be a conspicuous morning star of stellar magnitude −2, situated in the constellation Aries. The planet will be in western quadrature with the sun on August 7. Jupiter will be in conjunction with Saturn on August 15, 13h, and will be situated 1° 17′ to the north of the latter at that time.

*Saturn.* Saturn will be a morning star, of stellar magnitude +0.5, during July and August. The planet will be in western quadrature with the sun on August 7. It is to be noted that Saturn and Jupiter will parallel each other quite closely in apparent motion during the summer months of 1940. As noted in the paragraph on *Jupiter*, the two planets will be in conjunction in right ascension on August 15. An occultation of Saturn will occur July 28, invisible from the United States.

*Uranus.* Uranus is situated in the western portion of the constellation Taurus, where it is moving slowly eastward in direct motion. The planet will be in western quadrature with the sun on August 19. On July 26, it will be situated about 1′ south of a 9.5 magn. star, B.D. +18°510, and about a degree southwest of the 5.5 magn. star, 13 Tauri. Apparent positions of the planet are as follows:

| | $\alpha$ h m | $\delta$ ° ′ |
|---|---|---|
| July 1 | 3 29.4 | +18 40.1 |
| August 1 | 3 33.9 | +18 56.1 |
| September 1 | 3 35.6 | +19 1.6 |

*Neptune.* Neptune is located in the evening sky, in the constellation Leo. A chart illustrating the apparent path of Neptune among the stars appears on page 11 of POPULAR ASTRONOMY for January, 1940.

## Asteroid Notes

By HUGH S. RICE

No one of the large asteroids (Big Four) is in a good place for observation this summer except Ceres, and even this planet is in the last part of its apparition. The following tabulation gives the places accurately enough so that Ceres can be plotted on a star chart and picked up with a small telescope, its motion from day to day distinguishing it from a star of like magnitude.

| | | |
|---|---|---|
| June 4, (0h U.T.) | ½° east of $\theta$ Leonis, | stellar magnitude 7.9 |
| June 24, " | 3° s.w. of $\beta$ Leonis, | stellar magnitude 8.2 |
| July 14, " | 1° n.w. of $o$ Virginis, | stellar magnitude 8.4 |

Two days after the last date, Ceres apparently passes just south of $o$ Virginis.

We give herewith the ephemerides of the best ones of the next brightest minor planets that come to opposition this summer. First is a tabulation of some data concerning them. In the third column, the reduction is the value to be added algebraically to the right ascension and declination, respectively, to bring the positions from the 1950 equinox to that of 1940, on account of precession of the equinoxes. Ephemerides now are commonly given for the equinox of 1950, and they might as well be given for this as for any other equinox, inasmuch as there may be any one of various dates to which the observer may wish to reduce the ephemeris, to match some given star chart. In the column of logarithms, $r$ is the distance of the planet from the sun, in astronomical units, and $\Delta$ is the distance from the earth.

The ephemerides were computed by the Coppernicus-Institut, at Berlin-Dahlem.

Eros comes to opposition on June 16, but as its position is in southern Scorpius, it will not be well placed for northern observers. At this apparition the magnitude is 11.8 and the log Δ, 9.840.

| Planet | Stellar magnitude | Reduction for α (m) | Reduction for δ (′) | Date of opposition | Log of $r$ | Log of Δ | Remarks |
|---|---|---|---|---|---|---|---|
| 72 Feronia | 10.5 | —0.6 | 0 | Jun. 19 | 0.311 | 0.015 | (1) |
| 679 Pax | 10.8 | —0.5 | 0 | Jun. 24 | 0.410 | 0.196 | (2) |
| 386 Siegena | 10.7 | —0.5 | 0 | Jun. 28 | 0.475 | 0.313 | (3) |
| 233 Asterope | 11.0 | —0.6 | —1 | Jul. 6 | 0.400 | 0.178 | (4) |
| 192 Nausikaa | 8.7 | —0.6 | —1 | Jul. 15 | 0.336 | 0.065 | (5) |
| 124 Alkeste | 10.0 | —0.6 | —2 | Jul. 27 | 0.400 | 0.176 | (6) |

Remarks:

(1) In southern Serpens Cauda. On May 27, just s. of M 16.
(2) In Scutum and Serpens Cauda.
(3) In Serpens Cauda and Ophiuchus.
(4) In Aquila and Scutum.
(5) In Sagittarius. On July 16, just s. of M 55.
(6) In Aquarius and Capricornus.

EPHEMERIDES OF ASTEROIDS. FOR 0h U.T. EQUINOX 1950.

72 FERONIA

| | | α (h m) | δ (° ′) |
|---|---|---|---|
| May | 27 | 18 13.2 | —15 36 |
| June | 4 | 18 7.8 | —15 3 |
| | 12 | 18 0.9 | —14 34 |
| | 20 | 17 53.1 | —14 12 |
| | 28 | 17 45.2 | —13 56 |
| July | 6 | 17 38.1 | —13 49 |

679 PAX

| | | α (h m) | δ (° ′) |
|---|---|---|---|
| June | 4 | 18 30.5 | — 6 52 |
| | 12 | 18 23.6 | — 7 32 |
| | 20 | 18 15.5 | — 8 25 |
| | 28 | 18 6.8 | —9 29 |
| July | 6 | 17 58.0 | —10 44 |
| | 14 | 17 49.8 | —12 6 |

386 SIEGENA

| | | α (h m) | δ (° ′) |
|---|---|---|---|
| June | 12 | 18 40.3 | + 5 11 |
| | 20 | 18 34.4 | + 5 18 |
| | 28 | 18 28.0 | + 5 11 |
| July | 6 | 18 21.5 | + 4 49 |
| | 14 | 18 15.3 | + 4 14 |
| | 22 | 18 9.8 | + 3 26 |

233 ASTEROPE

| | | α (h m) | δ (° ′) |
|---|---|---|---|
| June | 20 | 19 14.3 | —11 44 |
| | 28 | 19 7.9 | —11 30 |
| July | 6 | 19 0.7 | —11 23 |
| | 14 | 18 53.7 | —11 22 |
| | 22 | 18 46.7 | —11 28 |
| | 30 | 18 41.0 | —11 40 |

192 NAUSIKAA

| | | α (h m) | δ (° ′) |
|---|---|---|---|
| June | 28 | 19 56.5 | —31 19 |
| July | 6 | 19 48.7 | —31 38 |
| | 14 | 19 39.7 | —31 48 |
| | 22 | 19 30.2 | —31 47 |
| | 30 | 19 21.1 | —31 35 |
| Aug. | 7 | 19 13.3 | —31 11 |

124 ALKESTE

| | | α (h m) | δ (° ′) |
|---|---|---|---|
| July | 6 | 20 46.1 | —13 25 |
| | 14 | 20 40.4 | —13 45 |
| | 22 | 20 33.7 | —14 12 |
| | 30 | 20 26.7 | —14 41 |
| Aug. | 7 | 20 19.7 | —15 13 |
| | 15 | 20 13.6 | —15 44 |

HAYDEN PLANETARIUM, AMERICAN MUSEUM OF NATURAL HISTORY,
NEW YORK CITY, MAY 14, 1940.

## Occultation Predictions

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

| Date 1940 | Star | Mag. | Immersion Greenwich C.T. | Immersion a | Immersion b | Immersion Angle E from N | Emersion Greenwich C.T. | Emersion a | Emersion b | Emersion Angle E from N |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | h m | m | m | ° | h m | m | m | ° |
| **Occultations Visible in Longitude +72° 30′, Latitude +42° 30′** | | | | | | | | | | |
| July 18 | BD—18°5079 | 6.5 | 4 50.1 | —1.5 | +0.6 | 49 | 6 0.0 | —1.9 | —1.6 | 291 |
| 21 | 72 B.Aqr | 6.5 | 6 19.1 | —2.8 | —1.1 | 116 | 7 14.8 | —0.7 | +2.2 | 197 |
| 22 | θ Aqr | 4.3 | 6 38.2 | —1.8 | +1.1 | 57 | 8 4.8 | —1.9 | +0.1 | 250 |
| 23 | 197 G.Aqr | 6.4 | 2 17.8 | —0.3 | +1.5 | 88 | 3 21.3 | —0.6 | +2.0 | 235 |
| Aug. 8 | 319 B.Vir | 6.3 | 0 49.7 | —0.5 | —2.9 | 162 | 1 25.4 | —0.4 | —0.4 | 235 |
| 14 | 95 B.Sgr | 5.8 | 3 15.3 | .. | .. | 20 | 3 54.9 | .. | .. | 323 |
| 15 | ρ Sgr | 4.0 | 0 50.8 | —1.8 | +0.8 | 90 | 2 15.3 | —2.0 | +0.5 | 254 |
| 21 | 98 B.Psc | 6.4 | 4 52.0 | .. | .. | 141 | 5 8.5 | .. | .. | 166 |
| 22 | 73 Psc | 6.2 | 5 42.0 | —2.0 | +0.9 | 96 | 6 53.6 | —1.2 | +2.5 | 211 |
| 26 | 63 Tau | 5.7 | 8 57.8 | —1.9 | +0.6 | 97 | 10 19.1 | —1.8 | +1.6 | 238 |
| 29 | 41 H³Gem | 6.0 | 6 36.9 | —0.1 | —0.1 | 137 | 7 14.2 | +0.4 | +2.4 | 224 |
| **Occultations Visible in Longitude +91° 0′, Latitude +40° 0′** | | | | | | | | | | |
| July 18 | BD—18°5079 | 6.5 | 4 13.4 | —2.0 | +1.6 | 46 | 5 22.9 | —2.3 | —1.1 | 301 |
| 21 | 72 B.Aqr | 6.5 | 5 34.6 | —2.1 | +0.6 | 101 | 6 47.4 | —1.6 | +1.9 | 217 |
| 22 | θ Aqr | 4.3 | 6 4.1 | —1.5 | +2.2 | 44 | 7 24.5 | —2.2 | +0.5 | 269 |
| 22 | 170 B.Aqr | 6.1 | 11 6.1 | —1.5 | —1.2 | 92 | 12 13.1 | —0.5 | +0.6 | 219 |
| 31 | Venus | —4.2 | 22 16.9 | 0.0 | —0.4 | 58 | 22 57.5 | +0.8 | —1.8 | 315 |
| Aug. 14 | 95 B.Sgr | 5.8 | 2 44.4 | .. | .. | 12 | 3 9.8 | .. | .. | 339 |
| 15 | ρ Sgr | 4.0 | 0 21.9 | —1.1 | +1.0 | 102 | 1 36.9 | —1.7 | +1.4 | 250 |
| 21 | 98 B.Psc | 6.4 | 4 12.6 | —1.2 | +0.6 | 117 | 4 58.1 | —0.4 | +3.3 | 195 |
| 22 | 73 Psc | 6.2 | 5 12.3 | —1.0 | +1.7 | 81 | 6 25.6 | —1.1 | +2.1 | 229 |
| 26 | 63 Tau | 5.7 | 8 28.5 | —1.1 | +1.5 | 84 | 9 44.3 | —1.3 | +1.7 | 247 |
| 28 | 124 H³Ori | 5.7 | 10 5.5 | —0.9 | +1.8 | 75 | 11 18.3 | —1.5 | +0.6 | 278 |
| **Occultations Visible in Longitude +120° 0′, Latitude +36° 0′** | | | | | | | | | | |
| July 16 | 29 Oph | 6.4 | 7 48.4 | .. | .. | 17 | 8 12.8 | .. | .. | 341 |
| 18 | BD—18°5079 | 6.5 | 3 14.2 | —1.2 | +1.7 | 71 | 4 25.8 | —1.4 | +0.4 | 289 |
| 18 | BD—18°5155 | 6.3 | 10 20.7 | .. | .. | 148 | 10 43.6 | .. | .. | 184 |
| 21 | 72 B.Aqr | 6.5 | 4 53.9 | —0.6 | +0.8 | 109 | 5 54.4 | —1.2 | +2.4 | 223 |
| 22 | θ Aqr | 4.3 | 5 24.2 | —0.6 | +2.4 | 45 | 6 27.3 | —1.1 | +0.9 | 281 |
| 22 | ρ Aqr | 5.4 | 7 29.9 | —2.2 | —0.2 | 120 | 8 19.6 | —1.0 | +3.5 | 194 |
| 22 | 170 B.Aqr | 6.1 | 10 8.3 | —2.1 | +1.1 | 62 | 11 38.9 | —1.9 | +0.5 | 242 |
| 24 | 60 B.Psc | 6.0 | 9 8.4 | —2.1 | +1.0 | 94 | 10 21.6 | —1.3 | +2.6 | 210 |
| 26 | 263 B.Psc | 6.4 | 11 1.6 | —1.3 | +2.5 | 46 | 12 27.1 | —2.3 | +0.8 | 260 |
| 31 | Venus | —4.2 | 22 16.0 | —0.4 | —1.3 | 97 | 23 16.6 | 0.0 | —1.4 | 280 |
| Aug. 1 | 26 Gem | 5.1 | 12 5.5 | +0.1 | +1.6 | 71 | 13 1.8 | —0.5 | +0.7 | 284 |
| 10 | μ Lib | 5.8 | 4 56.2 | —1.0 | +0.4 | 49 | 5 39.7 | —1.2 | —3.1 | 333 |
| 14 | 95 B.Sgr | 5.8 | 1 26.0 | —1.7 | +2.5 | 52 | 2 25.0 | —1.2 | —0.5 | 313 |
| 22 | 73 Psc | 6.2 | 4 54.8 | +0.1 | +1.5 | 74 | 5 56.1 | —0.3 | +1.7 | 245 |
| 22 | 88 Psc | 6.2 | 12 26.7 | —1.4 | +2.6 | 26 | 13 34.9 | —2.3 | —2.1 | 285 |
| 24 | 38 Ari | 5.2 | 8 58.4 | —2.1 | —0.3 | 122 | 9 43.0 | —0.1 | +4.1 | 193 |
| 25 | 30 B.Tau | 6.5 | 11 23.0 | —1.7 | +2.0 | 61 | 12 51.7 | —2.3 | +0.6 | 262 |
| 26 | 63 Tau | 5.7 | 8 10.9 | +0.1 | +1.7 | 65 | 9 11.1 | —0.5 | +1.2 | 268 |
| 28 | 124 H³Ori | 5.7 | 9 50.3 | +0.2 | +1.9 | 59 | 10 43.9 | —0.6 | +0.5 | 291 |
| 30 | 30 B.Cnc | 6.1 | 11 2.3 | +0.2 | +1.1 | 88 | 11 56.9 | —0.2 | +0.7 | 282 |

# Comet Notes

By G. VAN BIESBROECK

In the course of last month no comets were under observation. Both periodic comets 1933 III (Giacobini-Zinner) and Faye remained too close to the sun to be observable. This condition will not be modified until late in the fall but then the comets will be far from perihelion and their observation is doubtful.

In the morning sky PERIODIC COMET 1929 III (NEUJMIN) should be looked for. Computations made by M. Ebell in 1929 showed that this object has a period of 10 years. H. Q. Rasmusen (Copenhagen) has computed the planetary perturbations that this object has undergone up to this year and this led to the following elements:

$$\left.\begin{aligned} T &= 1940\ \text{May}\ 8.26\ \text{U.T.} \\ \omega &= 140.865 \\ \Omega &= 158.423 \\ i &= 3.690 \end{aligned}\right\} 1950.0$$
$$e = 0.58517$$
$$a = 4.88926$$
$$\text{Period} = 10.811\ \text{years}$$

giving the ephemeris:

| 1940 $0^h$ U.T. | (1940.0) $\alpha$ h m | $\delta$ ° ′ | ——Distance from—— sun | earth |
|---|---|---|---|---|
| June 4 | 22 43.7 | −5 51 | | |
| 12 | 22 55.0 | 4 51 | 2.053 | 1.653 |
| 20 | 23 5.1 | 3 59 | | |
| 28 | 23 13.9 | 3 17 | 2.080 | 1.528 |
| July 6 | 23 21.1 | 2 44 | | |
| 14 | 23 26.7 | 2 24 | 2.118 | 1.418 |
| 22 | 23 30.5 | 2 17 | | |
| 30 | 23 32.5 | −2 22 | 2.163 | 1.322 |

The maximum brightness is expected in July when the comet is favorably situated in the constellation of Aquarius. However, the original elements used in the prediction depend on observations covering an interval of 27 days only. This makes the position quite uncertain after an interval of more than 10 years.

Williams Bay, Wisconsin, May 10, 1940.

# METEORS AND METEORITES

## Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

On the evening of 1938 July 26 at 9:02 E.S.T., a brilliant fireball crossed the country from the northwestern corner of New Jersey to the Vermont-New Hampshire border. Due to the hour and season, it was seen doubtless by thousands of people. Mr. Claude H. Smith of Waterloo, New York, who was the A.M.S. regional director for that state, undertook the gathering of data. Independently, Mr. Charles A. Federer of the Hayden Planetarium in New York City, who indeed witnessed the fireball, gathered data there, and Dr. Fletcher Watson of Harvard College Observatory also gathered data in New England. At the time, I made the suggestion that it would be of interest to have each of the three groups of data worked up independently to show how near three computers would agree in the final results. So I encouraged Mr. Smith, who had put great trouble and interest into gathering data, both by letter and personal interviews, to make a solution. This he did very promptly and a month or so later sent his results to me for any needed revision. This was about September, 1938. I then had one of our assistants make a new plotting for the end points, as a check. I then saw that the data were contradictory but press of other work forced me to lay the matter aside. I was only

able to take it up about a month ago for completion. However, the whole thing had to be done over again because first Mr. Smith and then I had used automobile maps upon which to plot our azimuth lines. When I checked the length of projected path, computing the distance by differences in latitude and longitude, I found an error of about 60 km due to the poor projection of the automobile map. I then prepared a sketch map, as usual, in proper projection and made a new solution. This should be a warning that automobile maps which cover several states must not be taken as being accurate as to scale. Indeed, they are not prepared for such scientific purposes.

Having finally determined the projected beginning and end points with what I believe to be moderate accuracy, I attempted to determine the heights and other results in the usual way. But from here on the 40-odd observations in my hands are inadequate and contradictory. My purposes therefore in publishing what I find are: first because Mr. Smith and those who aided him should have at least this much recognition for their trouble, secondly that I think it of some interest to see how nearly I can come to the truth in a case where the data are as stated, but where my solution can eventually be compared with a solution based upon possibly ten times as many reports, many of them doubtless by trained observers and by persons placed in strategic positions for the fireball in question. This statement is made because I am informed by Mr. Federer that meantime the immense number of reports he had collected has been added to an already large number in Dr. Watson's hand, so eventually we may expect a very excellent solution by the latter. I repeat that it is of interest to see how near an admittedly poor solution will come to a good one. If the results should agree fairly well, it will increase our confidence in the way data are handled here in a difficult case. If they do not agree, it would be a proof that solutions based upon such data should have very low weight. Again I wish to say that Mr. Smith did all he could in an efficient way to gather data in his territory, and he himself made a solution. That I had to do it over is due mostly to the map he used, but having his results, already arranged in order and good form, has been of the greatest service to me. Whatever credit there may be in this case deservedly goes to him.

In the table that follows, I feel more confident of the coördinates of the projected path than anything else; next, that the path did not have much of a slope to the horizontal. I should hardly expect therefore that the altitude of the radiant point should be wrong by as much as $\pm 5°$, the azimuth by less. The heights, particularly the end point, gave more trouble. As to the end point the data are so wildly contradictory that I can only assume the fireball was lost to sight before extinction, due to haze, faintness, or obstructions, to the better observers located near its southern end because there are such positive statements that its altitude was low by observers near the northern end. If we assume, on the contrary, that the observers near the southern end actually did see the end of the fireball's path, the average of the altitudes for the end height, given by the four best observers, would be 73 km. This latter value would make the path so nearly horizontal (only 5° from it) that it is believed observers to the side would not almost unanimously have stated there was a considerable sloping to the north. Indeed the average of 17 estimates is $15° \pm$. This latter consideration was a very strong incentive to use the lower height. Obviously, the length of path and velocity are practically the same whichever height were chosen, the radiant, however, would have an altitude of only 5° instead of 14°, the azimuth remaining unchanged.

Averaging up the estimates of brightness or apparent size, for it is often impossible to differentiate in the reports, the fireball probably had an apparent disc of

about 10′ in diameter and certainly gave many times the light of Venus. While a variety of colors were assigned, yellow predominates in the reports to such a large extent that it may be taken as the real color with little fear of error. No long-enduring train was left, though "sparks" are mentioned as following just after the head. No sound was heard nor was there an actual "explosion" at end though there were certainly flares of more brilliant light at times during its course. The body, due perhaps to the denser part of its train just behind the head, was described as elongated rather than spherical. Tabular results follow:

| | |
|---|---|
| Date | 1938 July 26, 9:02 P.M., E.S.T. |
| Began over | $\lambda$ 74° 38′ W, $\phi$ 41° 12′ N |
| Ended over | $\lambda$ 72° 14′ W, $\phi$ 43° 32′ N |
| Sidereal time at end point | 262°.5 |
| Beginning height | 95 km |
| End height | 17 km |
| Length of path | 335 km |
| Projected length of path | 324 km |
| Duration | 8.6 seconds (28 estimates) |
| Apparent velocity | 39 km/sec |
| Radiant uncorrected | $a$ 37° $h$ 14° $\alpha$ 222° $\delta$ —24° |
| Zenith correction (parabolic) | —13° |
| Radiant corrected | $a$ 37° $h$ 1° $\alpha$ 216° $\delta$ —36° |

It will be noted that the zenith correction is very large; it is based upon the assumption of parabolic velocity. Were the velocity smaller, the correction would be larger. Its size is due both to great zenith distance of the radiant and to the radiant being nearly as far as possible (actually about 170°) from the meteoric apex. Due to the uncertainty of its position, from causes stated, the right ascensions and declinations have not been calculated but simply measured approximately from a large globe. It seems that the path would have been practically horizontal but for the earth's attraction.

The following persons sent in, with their reports, either diagrams, compass directions, or positions referred to stars. Hence their reports are more valuable.

W. M. June, Syracuse, N. Y., E. Bartkowiak, Jamesville, N. Y., F. L. Irish, Syracuse, N. Y., G. B. Potter, Middletown, N. Y., H. A. Wakehon, Yorkville, N. Y., H. S. Starbird, Onandaga Hills, N. Y., Mrs. M. S. Button, Chittenango, N. Y., D. W. Rosebrugh, Poughkeepsie, N. Y., C. A. Federer, New York, N. Y., Lt. Com. B. J. Powell-Tuck, R.N.R., Woodside, N. Y., R. P. Nelson, S. Norwalk, Conn., Miss O. M. Abbott, Lakeport, N. H., L. M. Summers, Greenfield, Mass., G. Green, Pittsfield, Mass., B. Topham, Toronto, Canada.

There were a score or more reports in addition with estimated coördinates or other descriptions. My sincere thanks are due to all the persons, mentioned by name or not, who kindly aided us in this investigation.

1940 May 18, Flower Observatory, Upper Darby, Pennsylvania.

# Contributions of the Society for Research on Meteorites

*Edited by* FREDERICK C. LEONARD,
Department of Astronomy, University of California, Los Angeles

*President of the Society:* H. H. NININGER, Colorado Museum of Natural History and American Meteorite Laboratory, Denver
*Secretary of the Society:* ROBERT W. WEBB, Department of Geology, University of California, Los Angeles

## A New Type of Nickel-Iron Meteorite from the Vicinity of the Arizona Meteorite Crater*

*By* H. H. NININGER

ABSTRACT

Among the meteorites gathered in the vicinity of the Arizona Meteorite Crater, a few individuals have been found whose etching pattern differs markedly from that of the typical Canyon Diablo irons; and chemical analysis reveals a considerably higher content of nickel: about 8.4%. According to accepted methods of identification, these distinctive individuals are regarded as belonging to a different type of meteorite. The majority of the irons of this new type show striking deformation of the kamacite plates, a feature almost unknown in the usual Canyon Diablo irons. An explanation for this is offered. It is suggested that the new type of nickel-iron meteorite from the region of Meteorite Crater be called Canyon Diablo, Arizona, No. 2.

The meteorites from the vicinity of the great Meteorite Crater near Winslow, Arizona, are well known to all students of meteorites. They have been discussed in numerous papers by American and European writers, ever since the first announcement of their discovery, by A. E. Foote, appeared in 1891, when he wrote in *The American Journal of Science,* 3rd Ser., **42**, 413-17, under the title of "A New Locality for Meteoric Iron, etc." In this paper, Foote referred to the material as the Canyon Diablo iron, for the reason that Canyon Diablo seemed to be the best-known geographical point of reference by which to describe the location. It is hardly necessary to recall that, at the time, no unusual significance had been attached to what is now correctly known as "Meteorite Crater" or, locally, as "Meteor Crater," in the immediate vicinity of which the find had been made. By virtue of this earliest designation, the irons from Meteorite Crater have always gone under the name of "Canyon Diablo meteorites." We shall, therefore, use this designation when referring to specimens of the structure and the composition described in the literature under that name.

In the course of the past several years, the American Meteorite Laboratory has sectioned numerous Canyon Diablo irons, in response to demands for specimens on the part of institutions and private collectors. Several hundred specimens have been subjected, thus, to the processes of polishing and etching. Nearly all of these etched surfaces have come under the scrutiny of the writer before the specimens left the Laboratory. We early recognized several types of structure as revealed by

*Read at the meeting of the Southwestern Division of the American Association for the Advancement of Science in Tucson, Arizona, on April 22, 1940.

the etching pattern. Most prominent of these is the typical, coarse Widmanstätten pattern, with kamacite bands of varying widths up to as much as 4 or 5 mm.; this structure has caused the Canyon Diablo meteorites to be placed in the group of coarsest octahedrites. This type of structure characterizes those portions of irons which have apparently not been subjected to any considerable heat. At its best, this type presents a most attractive and beautiful pattern. Adjoining plates, or groups of plates, stand out in bold contrast by virtue of the different ways in which they reflect the light. This circumstance gives an etched surface a lively and variegated pattern. In other parts of the same iron, or throughout the entire mass of some individuals, may be found a type of pattern which is strikingly weak by comparison. Though the same outline is present, the surface is so dull that one can with difficulty discern the outline. This dullness is due to granulation by heat; it is like the narrow zone of alteration observed at the surfaces of certain freshly fallen iron meteorites; only here, a large mass of the iron has been affected. In both of these types there is found comparatively little schreibersite.

A third type is abundantly beset by bars of schreibersite, which, to a large extent, conform in their arrangement to the kamacite plates. Since this phosphide is unaffected by the acid, it appears very prominently on the etched surface, more or less obscuring the Widmanstätten pattern, which, in this type of specimen, is composed of noticeably smaller units, so that the pattern is not so coarse as that in types 1 and 2. In a fourth type, we find this same schreibersite-beset pattern granulated by heat, but the appearance is not strikingly different in these last two types for the reason that the conspicuous array of schreibersite plates subdues the less-prominent kamacite. It should be pointed out, however, that, where the kamacite has not suffered alteration by heat, its light-reflecting properties produce the same beautiful, variegated, and lively pattern, regardless of whether the plates are large or small.

All of the four types previously described may be regarded as belonging to one and the same kind of meteorite, according to the accepted designation; in fact, it is possible to find all four types in a single specimen. Types 1 and 2 are found often in the same section, and, likewise, types 3 and 4; but rarely are all four types found in a single section.

In 1936, while we were etching a freshly sectioned lot of small Canyon Diablo irons that had been purchased from Mr. H. Locke of Winslow, two irons were found to respond in a different manner to the process. These developed a pattern that was recognized at once as being different from any of all of the four types with which we had become familiar in the Canyon Diablo irons. Schreibersite was not abundant in any of the four sections which came from these two irons, yet the kamacite plates were even smaller than in types 3 and 4, previously described. Taenite was more prominent, and the plates in no case presented the striking contrasts due to differences in their light-reflecting properties, which we had noted in the normal Canyon Diablo kamacite; yet these specimens showed no signs of alteration by heat; here, then, was something evidently new. We laid the specimens aside for future reference and waited to see whether other similar specimens would be found. They were. In 1939, in another lot of specimens, two other small individuals were discovered. These showed the same narrow kamacite plates and the same prominences of taenite and, in addition, the heat alteration, not only in the granulation of the kamacite but also in a very conspicuous deformation of the plates by bending. Schreibersite was present but was disposed in a different manner from that which is most common in the Canyon Diablo irons. A few months ago, Mr. John M. Grieger of Pasadena, California, sent me three sections of a

Canyon Diablo iron for etching. At once the etching pattern of this was recognized as being not that normal to a Canyon Diablo iron. Comparisons promptly indicated that the pattern was identical with that of our previous abnormal finds. Mr. Grieger was apprised of the facts and, by exchange, two of the slices were acquired for further investigation. A piece of one of these was sent to Mr. F. G. Hawley of Miami, Arizona, for analysis. His results showed the nickel content to be 8.42%, in contrast with the 5% to 7% of nickel which has been reported by

FIGURE 1
A POLISHED AND ETCHED SECTION OF THE WELL-KNOWN TYPE OF CANYON DIABLO METEORITE, No. 1

various investigators for the Canyon Diablo irons. I believe that these five irons should be regarded as belonging to a different type of meteorite from that known as Canyon Diablo, because of their structural peculiarities and their difference in chemical composition. We may list their structural peculiarities as follows:

1st: the smaller kamacite plates or finer crystallization;
2nd: the great prominence of taenite;
3rd: the different light-reflecting properties of the kamacite;
4th: the different arrangement of the schreibersite; and
5th: the prevalence of deformation of the crystalline structure.

Deformation of structure, *i.e.*, the bending of the kamacite and taenite plates, is not common in nickel-iron meteorites; yet it is by no means unknown. It has

been noted in Amalia Farm (or Bethany, Great Namaqualand, South Africa), Glorieta Mountain (New Mexico), Woods Mountain (North Carolina), Xiquipilco (Mexico), Henbury (Australia), and a few others. I have found it in only one of the many regular Canyon Diablo irons which have passed through our Laboratory; yet it is present in four of the five individuals which form the subject of this paper. An attempt to explain the apparent intermingling of these two kinds of meteorites in the same area will offer a possible answer to the question of why deformation prevails in this minor member of what appears to have been a dual fall.

The mass which produced the Arizona Crater has been variously estimated at from 200,000 to 12,000,000 tons. We are probably safe in assuming that the actual weight lay somewhere within these wide limits. Such a mass, traveling through space, might, in course of time, by its gravitational attraction, capture other small meteorites which chanced to come under its influence. Such captives would be most likely meteorites whose courses tended to parallel the course of the larger body. The captives would trail behind the captor spirally, somewhat after the manner of the planets revolving around the sun in its motion through space. When the larger meteorite with its "satellites" collided with the earth, blazing a fiery trail through the atmosphere,these smaller members would be spared much of the devastating frictional encounter which would work destruction to the forward and lateral surfaces of the leader. However, the "satellites" would be enveloped in the super-heated atmosphere which closed in behind the main mass. They would be spared surface ablation and would suffer greater heat penetration in varying degrees, depending upon their respective positions in the train. On the whole, these "satellites" would be subject far more to moderate heating and consequent deformation than to surface ablation.

In support of this view, it is interesting to note that, with the exception of Woods Mountain (North Carolina), all of those meteorites previously named, in which deformation has been noted, are known to have been members of considerable showers. Three of them are known to belong to showers associated with meteorite craters, and there is no certainty that craters were not formed in connection with the other falls represented. It is interesting to note also that the two members of these five, one of which showed but very little deformation at one end and the other none at all, did not show any evidence of granulation from heat. The other three, which were granulated throughout, showed also pronounced deformation of plates.

The writer has made a careful study of several oriented metallic meteorites and has found it to be the rule that heat penetration is deepest, always, on the rear side or base of the meteorite. The explanation offered is that, on the forward and lateral sides, ablation is so rapid that it overtakes the heat conduction, while on the rear side, which is sheltered from the air-blast, the condition is more like that in a furnace. The small "satellites" under discussion received this "furnace treatment" and became plastic, so that, under the strain of impact, they were deformed, as their crystalline structure now reveals.

Another consideration which might explain the intermingling of two falls in the same territory is that the same area has been visited by two meteorite falls at different times. Such an occurrence is not impossible, for the writer has found such an intermingling in certain other instances. In the instances of this kind thus far found, however, it has been possible, always, easily to determine that one of the falls had been on the earth much longer than the other. In the case of the

Canyon Diablo irons, however, there is no indication of any longer exposure to weathering in the one group of irons than in the other.

It should be noted that a small stony meteorite (cataloged as Coon Butte, Arizona) was found by D. M. Barringer and S. J. Holsinger about one mile west of Meteorite Crater, in 1905. The writer has examined this meteorite and has no doubt that it represents a much more recent fall than that which produced the Crater. The fact that two falls at different times are thus established for this same area would seem to render a third visitation less likely.

FIGURE 2
A POLISHED AND ETCHED SECTION OF THE NEW TYPE OF METEORITE FROM THE REGION OF METEORITE CRATER, CALLED IN THIS PAPER "CANYON DIABLO NO. 2"
(Note the deformation of the kamacite bands.)

If we may think of the crater-forming agency as having been a comet, we should naturally conclude that more than one meteorite was involved in the impact. It is by no means unlikely that a more thorough investigation would reveal that yet other participants in this great collision could be identified. Except in the immediate vicinity of the Crater, however, the great expanse of desert in which they may lie has never been carefully investigated.

It is suggested that this new type of nickel-iron meteorite from the region of Meteorite Crater be referred to under the name of Canyon Diablo, Arizona, No. 2.

### Members Elected as Fellows of the Society

Under date of May 1, 1940, the Council has elected the following members to fellowship in the Society:

Dr. Virgil E. Barnes, Bureau of Economic Geology, University of Texas, Austin, Texas.

Dr. N. T. Bobrovnikoff, Perkins Observatory, Ohio Wesleyan University and Ohio State University, Delaware, Ohio.

Dr. Arthur L. Coulson, Geological Survey of India, Calcutta, *India.*

Dr. Adolf H. Kunz, Department of Chemistry, University of Oregon, Eugene, Oregon.

Professor J. O. Lord, Department of Metallurgy, Ohio State University, Columbus, Ohio.
Dr. William H. McCrea, Department of Mathematics, Queen's University, Belfast, *Northern Ireland.*
Dr. W. Carl Rufus, Observatory, University of Michigan, Ann Arbor, Michigan.
Dr. B. M. Shaub, Department of Geology, Smith College, Northampton, Massachusetts.
Dr. John S. Stevenson, Department of Mines, Victoria, B. C., *Canada.*
Mr. Clyde W. Tombaugh, Lowell Observatory, Flagstaff, Arizona.
Dr. Fred L. Whipple, Harvard College Observatory, Cambridge, Massachusetts.
Dr. Arthur Berkeley Yates, Department of Geology, International Nickel Company of Canada, 3 Park Street, Copper Cliff, Ontario, *Canada.*

ROBERT W. WEBB, *Secretary*

# VARIABLE STARS

## Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

*The Longest Long-Period Variable:* In the course of the examination of a spectrum plate of the region of Monoceros, Mrs. Margaret Walton Mayall has discovered, from the appearance of bright emission lines, a new long-period variable, 0720*03*, which proved, upon further investigation, to have the longest period yet found for a variable of this type. The period is four years in length—the average period for long-period variables is nine to ten months—and the possibility of there being a smaller multiple of this value is precluded by the completeness of the observed light curves.

The star has been observed on 800 Harvard plates covering the years 1890 to 1940; and twelve cycles, averaging 1380 days each, have been more or less thoroughly observed. The magnitude varies between 10.0 and 13.0; the maxima are decidedly narrower than the minima; the increase in light is rapid compared to the decrease; and, as is found in most of the other very long, long-period variables, there is a marked tendency to a still-stand at and following minimum phase.

The variable star VX Sagittarii, 1802*22*a, with a period of just under 700 days, is the longest, long-period variable previously known. It varies between the eighth and the eleventh magnitudes. The newly discovered long-period variable accordingly has a period approximately twice as long as that of VX Sagittarii, and in form of light curve closely resembles the curve derived for R Volantis, period 445 days; Z Tauri, 500 days; V Camelopardalis, 519 days; RS Tauri, 549 days; and S Cassiopeiae, 612 days.

*Light Curve of l Carinae:* A recently published list of observations of variable stars by the Variable Star Section of the New Zealand Astronomical Society contains nearly 1500 observations of the Cepheid variable *l* Carinae, 0942*62*, a spectroscopic binary. These observations combined with the data obtained by members of the A.A.V.S.O. in the southern hemisphere, in particular by A. W. J. Cousins

of South Africa and J. M. Baldwin of Australia, give a sufficient amount of material for one to discuss in some detail the light curve and period of this galactic Cepheid which has a longer period, namely 35.5 days, than is usually found in this class of variable.

After light curves had been plotted from all the available observations, provisional dates of maxima were determined for each cycle, and with these as zero

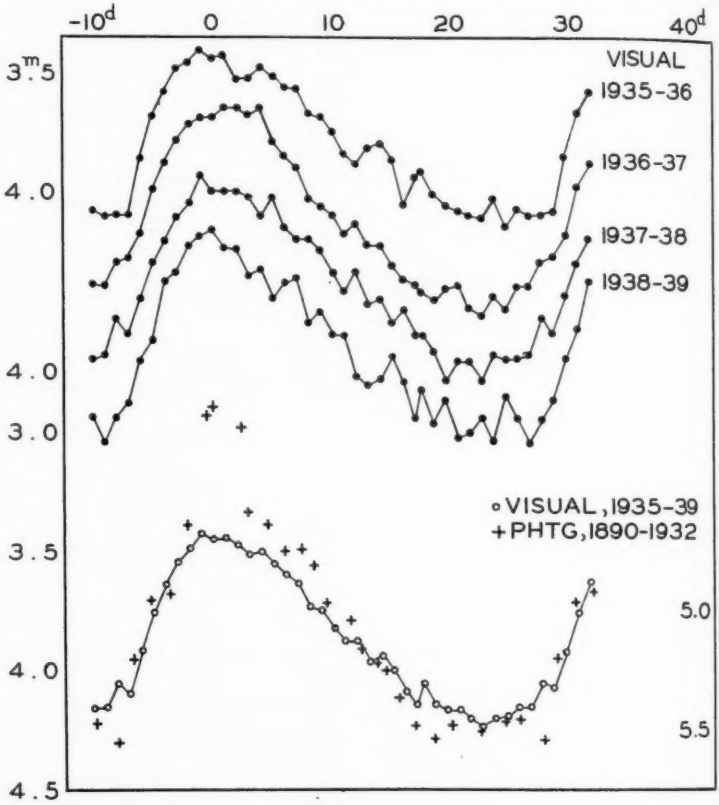



FIGURE 1
LIGHT CURVES OF *l* CARINAE

points of reference mean light curves for different intervals of years were derived under daily means. Usually about thirteen cycles were used for each mean light curve, providing four individual curves. Finally a mean light curve was derived from all the observations, covering in general the years 1935 to 1939 inclusive. These curves are shown in Figure 1, the four individual curves (top) being separated by a quarter of a magnitude in ordinate. In the final visual mean curve an average of 30 daily means are included in each point, or a total of more than 3000 individual observations. Although some slight differences occur between the sep-

arate curves, in general the shape of each is the same—a somewhat rounded maximum and a gradually decreasing fall to minimum, which occurs about 13 days before maximum is reached. The ratio of increase to decrease is about two to one; twice as rapid when rising as when falling. The visual mean range in variation is 0.8 of a magnitude—from $3^{M}.4$ to $4^{M}.2$.

A comparison of these visual mean light curves with the photographic curve derived by L. V. Robinson is of interest. The agreement is excellent, except at actual maximum phase: the photographic curve instead of rounding off as in the visual curve presents a decidedly pointed maximum. Otherwise one finds that in general the photographic curve is about $1^{M}.25$ fainter than the visual curve. For comparison, the photographic curve (represented by disconnected crosses) corrected by $1^{M}.25$, is plotted with the visual mean curve (connected open circles).

The period obtained from the visual observations here discussed is $35^{d}.493$. If we use the observations by Innes in 1896 and those by Cousins in 1920, a value of $35^{d}.527$ is found for those years. Between 1920 and 1934 the period is best satisfied by a value of $35^{d}.554$. The mean period from 1896 to 1939 inclusive is $35^{d}.5323$. Using the final visual mean light curve as a model, one may read off anew the dates of maxima and minima given in the table.

The several columns contain for maxima and minima respectively; N, the current number of maximum or minimum; the Julian date; the first differences between the dates of consecutive maxima and minima, and the average deviation—negative values in Italics— of these differences from a mean period of $35^{d}.5$. The mean average deviations for maximum and minimum are $\pm 0^{d}.64$ and $\pm 0^{d}.70$, respectively.

*l* CARINAE

| N | J.D. Max. 2422 | Δ d | A.D. d | J.D. Min. 2422 | Δ d | A.D. d |
|---|---|---|---|---|---|---|
| 0 | .. | .. | .. | 7753.9 | 37.2 | 1.7 |
| 1 | 7768.6 | 34.8 | *0.7* | 7791.1 | 35.6 | 0.1 |
| 2 | 7803.4 | 36.1 | 0.6 | 7826.7 | 35.1 | *0.4* |
| 3 | 7839.5 | 34.2 | *1.3* | 7861.8 | 34.4 | *1.1* |
| 4 | 7873.7 | 35.9 | 0.4 | 7896.2 | 37.0 | 1.5 |
| 5 | 7909.6 | 35.7 | 0.2 | 7933.2 | 34.5 | *1.0* |
| 6 | 7945.3 | 35.2 | *0.3* | 7967.7 | 35.0 | *0.5* |
| 7 | 7980.5 | 35.3 | *0.2* | 8002.7 | 34.6 | *0.9* |
| 8 | 8015.8 | 34.7 | *0.8* | 8037.3 | 36.1 | 0.6 |
| 9 | 8050.5 | 35.5 | 0.0 | 8073.4 | 35.6 | 0.1 |
| 10 | 8086.0 | 35.8 | 0.3 | 8109.0 | 35.5 | 0.0 |
| 11 | 8121.8 | 35.7 | 0.2 | 8144.5 | 36.2 | 0.7 |
| 12 | 8157.5 | 36.1 | 0.6 | 8180.7 | 35.6 | 0.1 |
| 13 | 8193.6 | 35.8 | 0.3 | 8216.3 | 35.7 | 0.2 |
| 14 | 8229.4 | 35.2 | *0.3* | 8252.0 | 34.4 | *1.1* |
| 15 | 8264.6 | 35.9 | 0.4 | 8286.4 | 34.6 | *0.9* |
| 16 | 8300.5 | 34.3 | *1.2* | 8321.0 | 34.8 | *0.7* |
| 17 | 8334.8 | 36.9 | 1.4 | 8355.8 | 35.8 | 0.3 |
| 18 | 8371.7 | 33.5 | 2.0 | 8391.6 | 35.7 | 0.2 |
| 19 | 8405.2 | 36.7 | 1.2 | 8427.3 | 36.1 | 0.6 |
| 20 | 8441.9 | 34.4 | *1.1* | 8463.4 | 36.2 | 0.7 |
| 21 | 8476.3 | 36.4 | 0.9 | 8499.6 | 37.3 | 1.8 |
| 22 | 8512.7 | 37.2 | 1.7 | 8536.9 | 35.9 | 0.4 |
| 23 | 8549.9 | 35.3 | *0.2* | 8572.8 | 34.1 | *1.4* |
| 24 | 8585.2 | 34.7 | *0.8* | 8606.9 | 34.9 | *0.6* |
| 25 | 8619.9 | 35.1 | *0.4* | 8641.8 | 35.6 | 0.1 |
| 26 | 8655.0 | 35.2 | *0.3* | 8677.4 | 35.6 | 0.1 |
| 27 | 8690.2 | 35.8 | 0.3 | 8713.0 | 35.1 | *0.4* |
| 28 | 8726.0 | 35.0 | *0.5* | 8748.1 | 35.8 | 0.3 |

*l* CARINAE *(Continued)*

| N | J.D. Max. 2422 | Δ d | A.D. d | J.D. Min. 2422 | Δ d | A.D. d |
|---|---|---|---|---|---|---|
| 29 | 8761.0 | 35.7 | 0.2 | 8783.9 | 34.3 | 1.2 |
| 30 | 8796.7 | 34.4 | 1.1 | 8818.2 | 35.9 | 0.4 |
| 31 | 8831.1 | 36.2 | 0.7 | 8854.1 | 38.2 | 2.7 |
| 32 | 8867.3 | 37.2 | 1.7 | 8892.3 | 34.0 | 1.5 |
| 33 | 8904.5 | 35.5 | 0.0 | 8926.3 | 34.7 | 0.8 |
| 34 | 8940.0 | 33.9 | 1.6 | 8961.0 | 35.8 | 0.3 |
| 35 | 8973.9 | 36.6 | 1.1 | 8996.8 | 36.5 | 1.0 |
| 36 | 9010.5 | 35.3 | 0.2 | 9033.3 | 35.7 | 0.2 |
| 37 | 9045.8 | 36.1 | 0.6 | 9069.0 | 35.9 | 0.4 |
| 38 | 9081.9 | 35.6 | 0.1 | 9104.9 | 34.7 | 0.8 |
| 39 | 9117.5 | 35.5 | 0.0 | 9139.6 | 34.4 | 1.1 |
| 40 | 9153.0 | 34.2 | 1.3 | 9174.0 | 36.0 | 0.5 |
| 41 | 9187.2 | 35.6 | 0.1 | 9210.0 | 35.3 | 0.2 |
| 42 | 9222.8 | 35.6 | 0.1 | 9245.3 | 36.1 | 0.6 |
| 43 | 9258.4 | 35.3 | 0.2 | 9281.4 | 34.6 | 0.9 |
| 44 | 9293.7 | 35.9 | 0.4 | 9316.0 | 36.3 | 0.8 |
| 45 | 9329.6 | 35.7 | 0.2 | 9352.3 | 35.8 | 0.3 |
| 46 | 9365.3 | 35.9 | 0.4 | 9388.1 | 36.3 | 0.8 |
| 47 | 9401.2 | 36.0 | 0.5 | 9424.0 | 35.0 | 0.5 |
| 48 | 9437.2 | 35.1 | 0.4 | 9459.4 | 32.9 | 2.6 |
| 49 | 9472.3 | 33.7 | 1.8 | 9492.3 | 35.5 | 0.0 |
| 50 | 9506.0 | 35.4 | 0.1 | 9527.8 | 38.2 | 2.7 |
| 51 | 9541.4 | 37.3 | 1.8 | 9566.0 | 35.4 | 0.1 |
| 52 | 9578.7 | 35.6 | 0.1 | 9601.4 | 34.3 | 1.2 |
| 53 | 9614.3 | 34.8 | 0.7 | 9635.7 | 36.1 | 0.6 |
| 54 | 9649.1 | 35.9 | 0.4 | 9671.8 | .... | ... |
| 55 | 9685.0 | .... | ... | ..... | .... | ... |

Incidentally the New Zealand publication referred to above presents the observations on 107 variable stars, mainly of long period, by 18 observers, totalling approximately 7350 estimates of magnitude. Of these, more than 85 per cent were made by "Sm," Mr. G. S. Smith, assistant director and recorder for the variable star section.

*The Variations in U Persei:* Not only does the long-period variable U Persei present very marked peculiarities in the form of its light curve from cycle to cycle, but there is some evidence of a change in the length of period over the nearly fifty years that the star has been under visual and photographic observation.

Father D. O'Connell in 1933 observed U Persei on Harvard plates covering the years 1899 to 1932 (see *Harvard Bulletin* 892), and visual observations have been practically continuous since 1905. The latter provide more completely observed cycles, because photographic observations from a single observing station cannot, of necessity, cover a star as closely as can visual observations made at many places.

The photographic curve can be readily adapted to the corresponding visual curve by an adjustment of one and a half magnitudes in the scale, doubtless because of the rather extreme redness of the variable. The photographic curve is observed to be fainter by this nearly constant amount. If we compare the magnitudes at maximum and minimum we find that the differences are essentially the same at both phases, $1^M.42$ for the former, and $1^M.41$ for the latter.

Although the mean light curves derived for different epochs all show the form typified by wide maxima and narrow minima, there are marked variations in the curve, especially at and near maximum phases. At times the maxima are well rounded and without pronounced still-stands, while at other times there are well-defined still-stands, occasionally approaching a definite secondary minimum. The

minima—not so well observed in the photographic curves—are usually sharply defined and of varying depths; and where both photographic and visual observations occur for the same cycle they agree in nearly every essential detail.

Mean light curves of U Persei derived for different epochs show more dissimilarities than are usually found for one particular long-period variable. This is especially noted when the mean light curves for the past seven years are compared with those of earlier years. The most recent curve has a considerably greater range of variation, $8^M.1$ to $11^M.3$, than the range prior to 1932, which was about $8^M.3$ to $10^M.5$. Throughout the entire observed variation of the star the difference in magnitude at minimum is much more marked than the difference in magnitude at maximum.

In looking for other variable stars which might be considered comparable to U Persei, we find relatively few among the several hundred long-period variables under observation. The following table lists those which have similar mean light curves of the "A" type—wider maxima than minima, the latter being steep and narrow—and approximately similar periods and ranges of variation. The greatest divergence from similarity is in the spectral type. While there is a comparatively large number of "A" type long-period variables, most of them have either considerably shorter or longer periods, or vary over a much greater or lesser range of magnitude than these listed.

| Design. | Name | Per. d | Max. Min. | Spec. | Range |
|---|---|---|---|---|---|
| 015254 | U Per | 320 | 8.3 - 10.8 | M6e | 2.5 |
| 024217 | T Ari | 314 | 8.8 - 11.0 | M6 | 2.2 |
| 053068 | S Cam | 326 | 8.4 - 10.4 | R8e | 2.0 |
| 070310 | R CMi | 338 | 8.0 - 10.9 | Se | 2.9 |
| 122532 | T CVn | 290 | 9.6 - 11.5 | M5 | 1.9 |
| 141567 | U UMi | 327 | 8.3 - 12.0 | M6e | 3.7 |
| 153378 | S UMi | 324 | 8.5 - 11.7 | M7e | 3.2 |

Long-period variables in general appear not to have undergone a definite or real change of period, but a few, such as R Hydrae and R Aquilae, have changed from longer to shorter periods, the former by twenty-five per cent over an interval of 200 cycles or 270 years, the latter by ten per cent in 85 cycles or 75 years.

U Persei had an average period of 315 days in 1903, 322 days in 1921, and 328 days in 1939. In spite of the fact that the minima were more sharply defined than the maxima (and accordingly one should be able to read off times of minima better when one uses the mean light curve method of determining the particular phases), the deviations from the assumed periods during these epochs are remarkably alike, about ±8 days for either phase in each epoch. The suggested lengthening of period for U Persei is not large—only 14 days or four per cent over an interval of about 40 years; but if the apparent change is borne out by future years of observation, it will be the first lengthening of period found for a long-period variable. For this reason alone the star should be carefully observed for many years to come.

*A.A.V.S.O. Nova Search Program:* The systematic search for bright naked-eye novae has again been launched with the hope that none shall escape early detection. Not since 1936 has a brilliant nova appeared. Sections along the Milky Way, measuring approximately ten degrees on a side, have been assigned to various A.A.V.S.O. observers. South African observers to the number of a dozen have agreed to coöperate so that the whole sky may be kept under surveillance. For the present the work is to be confined to a survey of the naked-eye stars; the visible dome of the sky is to be searched once each clear night to check all objects brighter

than the second magnitude. As there are less than a hundred of such stars, not more than thirty would be visible at any one place at any one time. Then, in his assigned region the observer is expected to identify all stars, down to the limit of naked-eye visibility, with those marked on the chart of that particular region and look for a possible stranger among them.

Cards for reporting the results of each month's search are provided by the Recorder. If the observer is practically certain of the presence of a new star, he should communicate the information at once to the nearest astronomical center or observatory for confirmation. "At once" cannot be emphasized too much, because observations made during the early stages of a nova's career are of the greatest importance. For a long time the results of such a systematic search on the part of the Association will doubtless be negative, but, aside from its scientific importance, the prompt detection of a spectacular nova will more than repay the discoverer for the effort expended. The A.A.V.S.O. awards its David B. Pickering Nova Medal to the original discoverer of a nova by visual methods. Who will be the next to receive such a medal?

*Observers and Observations:* The following list is of observers and observations received during the month of April:

| Observer | Var. | Obs. | Observer | Var. | Obs. |
|---|---|---|---|---|---|
| Albrecht | 8 | 15 | Kozawa | 20 | 77 |
| Baldwin | 51 | 56 | Lundquist | 13 | 29 |
| Ball, A. R. | 28 | 39 | Mages | 4 | 4 |
| Ball, J., Jr. | 7 | 7 | Maupomé | 82 | 82 |
| Blunck | 11 | 11 | Moore | 7 | 7 |
| Bouton | 29 | 30 | Needham | 14 | 14 |
| Buckstaff | 14 | 47 | Palo | 32 | 32 |
| Chandra | 194 | 555 | Parker | 17 | 25 |
| Chilton | 1 | 1 | Peltier | 20 | 58 |
| Cilley | 27 | 51 | Plakidis | 13 | 15 |
| Cousins | 33 | 101 | Prinslow | 3 | 3 |
| Dafter | 9 | 23 | Purdy | 10 | 10 |
| Diedrich | 4 | 7 | Rense | 11 | 12 |
| Ensor | 39 | 48 | Rosebrugh | 14 | 82 |
| Escalante | 56 | 80 | de Roy | 15 | 78 |
| Fernald | 71 | 92 | De Santis | 9 | 9 |
| Gregory | 75 | 80 | Saxon | 19 | 19 |
| Griffin | 38 | 42 | Schoenke | 4 | 7 |
| Halbach | 1 | 1 | Sill | 18 | 18 |
| Harris | 81 | 81 | Smart | 2 | 2 |
| Hartmann | 98 | 104 | Smith, F. P. | 8 | 8 |
| Heckenkamp | 2 | 8 | Smith, L. | 12 | 12 |
| Holmes, Mrs. | 5 | 5 | Topham | 61 | 61 |
| Holt | 108 | 269 | Treadwell | 5 | 5 |
| Houghton | 80 | 155 | Walton | 12 | 25 |
| Irland | 8 | 15 | Webb | 11 | 11 |
| Jones | 22 | 40 | Weber | 8 | 9 |
| Kearons, Mrs. | 67 | 182 | Williams | 15 | 57 |
| Kelly | 19 | 24 | Yamada | 8 | 21 |
| deKock | 62 | 293 | Yamasaki | 9 | 9 |
| Kotsakis | 8 | 24 | | | |
| | | | 61 | (Totals) | 3282 |

May 16, 1940.

# Notes from Amateurs

### Amateur Astronomers Association of Pittsburgh, Pennsylvania

On May 10 our association held its annual meeting and the following named persons were elected as officers: F. M. Garland, president; H. Clinton Kyle, vice-president; Willard A. MacCalla, treasurer; Leo N. Schoenig, secretary.

Plans were discussed in preparation for the National Amateur Astronomers Convention to be held in Pittsburgh July 5, 6, and 7, and all indications are that amateurs representing practically every district in the United States will be present.

F. M. Garland.

1006 Davis Avenue, N.S., Pittsburgh, Pennsylvania, May 11, 1940.

### The Cleveland Astronomical Society

The last of the winter series of meetings was held at the Y.M.C.A., East 22nd Street and Prospect Avenue, April 26, 1940, at 6:30 P.M. This was the dinner meeting which winds up the winter activities. Our speaker was Paul Herget, Ph.D., of the Cincinnati Observatory, and the subject, "The Eleven Satellites of Jupiter." Dr. Herget has the distinction of being the one who computed the orbits of the two new satellites of Jupiter when they were first discovered. He is a young man of great enthusiasm, a fluent speaker and is very well versed in astronomy and particularly in the field of the Jovian system. He held the attention of a mixed audience throughout the lecture. We are all looking forward to the completion of the new observatory which Dr. Nassau assured us would be ready for our meetings this fall. The Schmidt telescope will not be finished at that time but the refractor will be available as usual. The Yoders have kindly invited us to hold our summer meeting with them sometime in July, the date to be announced later.

Don H. Johnston.

Euclid Beach Park, Cleveland Ohio.

### Aperture and Focal Length

Makers of refracting telescopes generally have adopted a ratio of one to fifteen between aperture and focal length or, as photographers would say, their objectives have a speed of F/15. This permits good chromatic and spherical correction with good defining and light collecting power. Such lenses give good tests on close double stars, faint stars, and nebulae. We sometimes see the statement that the apparent disc of a star decreases with increase of the diameter of the objective or aperture, so it would seem that a large objective must give better definition than smaller lenses. Since no mention is made of focal length one does not know whether this statement is based on experiments made with lenses of various sizes and focal lengths, or with a large lens stopped down.

In most telescopes star images appear with one or more bright rings and if we are viewing close double stars the powers used must be great enough to place the images beyond these rings of light. This is particularly true if a bright star has a close and faint companion.

In such cases if we could reduce the glare of the bright star the faint companion could be more easily detected, but since stopping down is said to increase the size of the apparent image of the bright star and would further dim the image

of the faint companion, such an expedient cannot be used. When we test defining or resolving power of a telescope on close doubles we are dealing with bright points and such a test, allowing for varying air conditions, affords a high degree of accuracy. When we come to use our telescopes on the moon or the planets, conditions and results are notably different. We have now no brilliant points of light such as the stars but much fine detail that experience shows us can be rendered difficult to see or entirely invisible by glare from bright portions of the image and by the purple haze common to properly corrected refractors. Bad seeing due to air waves or other causes add greatly to the difficulty of seeing fine planetary detail also.

Planetary observers have found that diaphragmming or stopping down the objective helps to correct these troubles, so that what was a brilliant but nearly blank image at F/15 becomes at F/25 a pleasing image as full of detail as a steel engraving. When referring to telescopes we list them as to size of objective and seldom or never mention their focal length. The Yerkes telescope has a focal length of nearly 800 inches which gives an F value of 20 for the 40-inch objective.

Dr. Lowell, for planetary observation, stopped down his 24-inch lens to from 12 to 18 inches and sometimes used color filters for better seeing of fine detail. He found that definition was thereby markedly improved. Professor A. E. Douglass in an article, "Atmosphere, Telescope and Observer," in POPULAR ASTRONOMY for June, 1897, reprinted in *Amateur Telescope Making, Advanced,* recommends diaphragmming the objective to reduce glare or effect of chromatic aberration and to reduce the effect of air waves so that definition and contrast of planetary detail be greatly improved. Professor W. H. Pickering in an article, "Reflectors versus Refractors," in POPULAR ASTRONOMY for March, 1930, reprinted in *Amateur Telescope Making, Advanced,* discusses the question of aperture and focal length and concludes that for planetary work long-focus lenses and mirrors are desirable. Louis Bell in "The Telescope" stated that small telescopes or large telescopes stopped down give better definition and more contrast than when large glasses are used at full aperture for planetary study. For nebulae, comets, and faint stars, full apertures are needed.

The Lowell refractor has a full aperture value of F/15.5. When stopped to 18 inches it is F/20.6 and at 12 inches it is F/31. This refractor has been fitted with an iris diaphragm much as is a photographic lens. In the photographic lens stopping down improves definition and increases depth of focus; in the telescope it does both and in addition reduces the bad effect of air waves.

With the kind of glass used at present for making telescope objectives it is said to be easier to correct them at F/15 than at longer or shorter ratios. For planetary use F/25 seems desirable and, since at best correction is only a compromise, planetary observers should select longer-focus lenses even though it means greater cost, longer telescopes, and larger domes. Long-focus objectives permit the use of long-focus eyepieces which is desirable.

Some great discoveries of the early days of observational astronomy were made with uncorrected single lenses of extremely long focus which tended to reduce the effects of aberration. Very small stops are not desirable for we get a pinhole effect which is worse than glare and tends to exaggerate all the defects of the eyepiece and especially adhering dust not otherwise noticeable. It does not seem desirable to select, grind, and polish large discs of glass into costly lenses and then to stop them down to little more than half their diameter so we can see well what we are looking at. It should be as easy to correct a small lens of a given focal length as a much larger lens of the same focal length, or suppose after the large

lens was finished the margin became chipped so that the lens needed to be cut down, we would then have a small lens with a long focus and improved definition for planetary observation. For dim objects short-focus lenses and mirrors are desirable and are coming into use rapidly especially for photography.

Planetary observation requires long-focus lenses for better definition. Achromatic concave lenses to increase focal length are in use but no report on performance seems to be available. Such a lens was used on the Lowell refractor to increase its focal length for planetary photography and similar lenses have been used elsewhere. The Mogeys make such lenses for use with their telescopes and perhaps other makers do also. Solar photographic telescopes have been made with objectives of 12 inches diameter and 135 feet focal length. This gives an F value of 135 which would cause a pinhole effect or serious marginal refraction in a small lens.

Direct observation and celestial photography are subject to various limitations and compromises and the amateur would do well to learn what others have learned by long experience so as to know what to expect from his apparatus and air conditions.

Perhaps it is well to keep in mind the kind of research to be taken up so that the proper apparatus may be selected, a long-focus telescope for planetary study, a general purpose telescope for stars and nebulae or short-focus lenses and mirrors for celestial photography. Deserving mention are the Schmidt camera and its modifications, some of which work at F/1. Comet finders consist of short-focus lenses or mirrors of relatively large diameter and are used with eyepieces designed to give a wide field of view, so as to catch dim objects such as comets usually are. The new 200-inch telescope is intended principally for celestial photography and at its prime focus it has a speed of F/3.3. The 200-inch mirror is being finished to the greatest possible perfection and is intended for photographing distant nebulae and faint stars, yet it is to be provided with an iris diaphragm. The Cassegrain focus has an F value of 16 and the coudé focus F/30, therefore it differs from other large reflectors chiefly in size. For visual observation of planetary detail it of course will have but little value.

W. E. Duckwall.

Hillsboro, Ohio.

## General Notes

**Dr. Henry Norris Russell** gave the ninth James Arthur lecture on Time and its Mysteries at the Gould Memorial Library, University Heights, New York City, on Tuesday, May 14. Dr. Russell's subject was "The Astronomical Time Scale."

**Dr. Harlow Shapley,** Paine professor of astronomy and director of the Harvard College Observatory, has been elected an honorary member of the Harvard class of 1910, in which year he received the degree of bachlor of arts from the University of Missouri. (*Science,* May 10, 1940)

**Mr. James Stokley** has resigned his position as director of the Buhl Planetarium, Pittsburgh, Pennsylvania. His successor, as director of the Buhl Planetarium, is Mr. Arthur L. Draper, formerly assistant curator at the Hayden Planetarium in New York City.

**Dr. Arthur H. Compton,** professor of physics at the University of Chicago, has been appointed dean of the physical sciences. He will succeed, on July 1, Dr. Henry Gordon Gale, who has served since 1925 as chairman of the department. Dr. Gale will become dean emeritus of the physical sciences. (*Science,* May 10, 1940)

**Mr. Leo J. Scanlon,** well known as an amateur astronomer and as the builder of the Valley View Observatory, near Pittsburgh, was married on April 30 to Miss Margaret Schwartz. They then left for a tour through the western states, making the large observatories on the Pacific Coast their principal objectives.

**The Rittenhouse Astronomical Society of Philadelphia** held its regular meeting on Friday, May 10, 1940, in the Hall of The Franklin Institute. Dr. Serge A. Korff, of the Bartol Research Laboratories, gave an illustrated talk on "Cosmic Ray Research," in which he demonstrated the apparatus used in this work.

### Observation of a Colored Solar Halo

On January 4, 1940, I had occasion to observe the extremely rare phenomenon of a reverse curve attached to a 46° sun-halo. I was able to photograph the curve, which showed the colors of the spectrum. The first photograph at 5:30 P.M. (legal hour of Rio de Janeiro), the second at 5:35 P.M. The observation was made at Sao Paulo, Brazil. The camera used was fitted with a Steinheil lens, and the exposure time was 1/50 of a second.

HERBERT LUFT.

## Book Reviews

### Publications Received

The publishers of POPULAR ASTRONOMY hereby acknowledge the receipt of the following named publications and express their great appreciation of the courtesy shown on the part of those who have sent them.

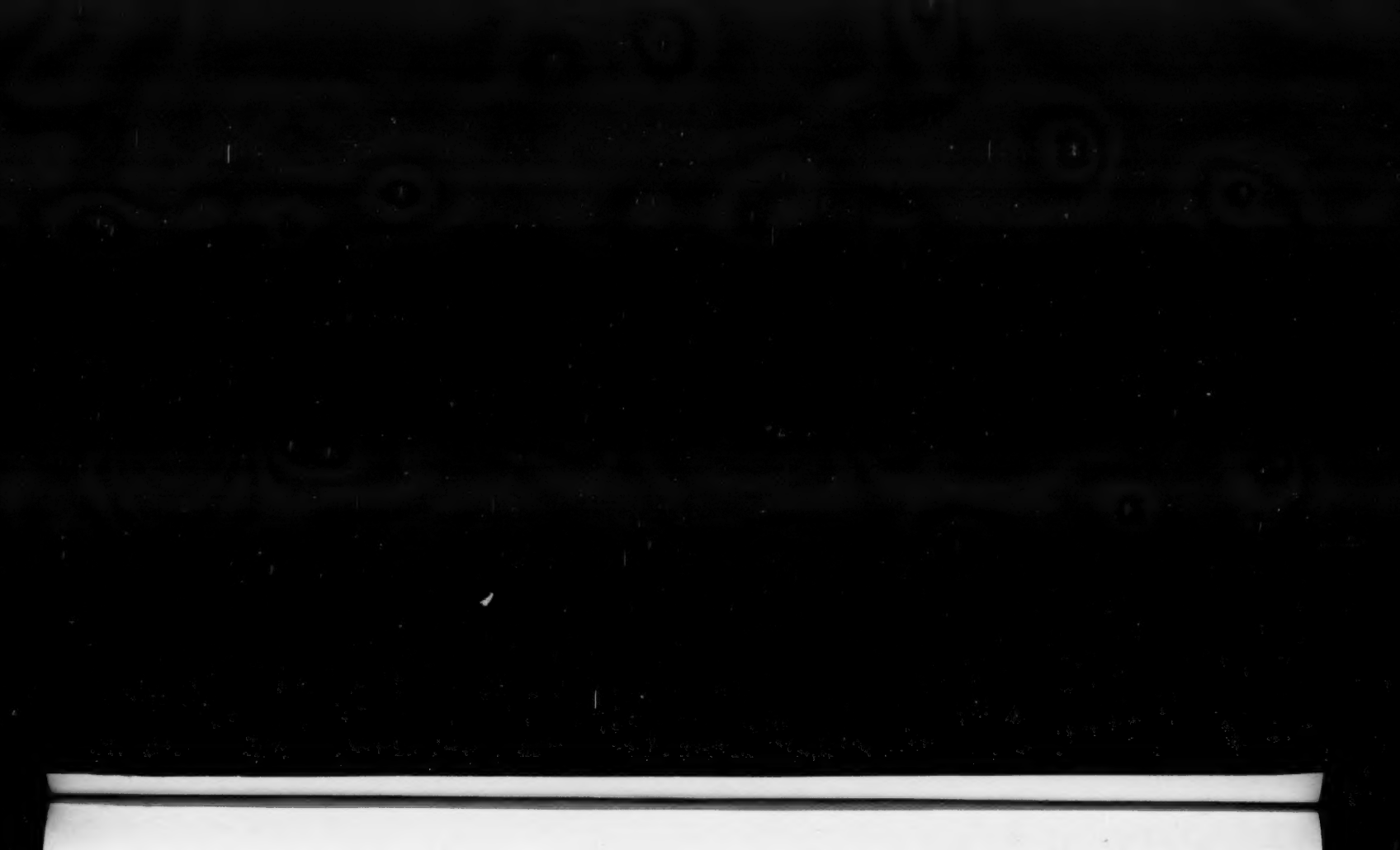
*Contributions from the Mount Wilson Observatory—*

No. 616. "Intensity Changes in Bright Chromospheric Disturbances," by R. S. Richardson.

No. 617. "Space Reddening in the Galaxy," by Joel Stebbins, C. M. Huffer, and A. E. Whitford.

No. 618. "The Mean Absolute Magnitude of Class-R Stars, by Ralph E. Wilson.

No. 619. "Spectra of M Supergiant Stars," by Lyman Spitzer, Jr.

No. 620. "Integrated Photographic Magnitudes of Sixty-Eight Globular Clusters," by William H. Christie.

No. 621. "The Colors of 1332 B Stars," by Joel Stebbins, C. M. Huffer, and A. E. Whitford.